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CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E, Para. 7.3	~~Eng'r. Data~~	LEM	NAS 9-1100	1/14/63

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REPORT

NO. LPR-550-4 DATE: 1 February 1964

QUARTERLY RELIABILITY STATUS REPORT [U]

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ENG. 345

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

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ABSTRACT

This Quarterly Reliability Status Report is submitted in fulfillment of the requirement of Paragraph 7.3 of Reference (a), and is the fourth in a series of reports to be submitted as part of the Reliability Plan.

1. INTRODUCTION AND SUMMARY

1.1 Introduction

The reliability estimates contained herein are based on the nominal LEM subsystem configurations as of 15 December 1963 and synchronous descent. The reliability estimate for the MIT Guidance and Navigation Equipment in the Navigation and Guidance function is based on the data obtained at MSC on 17 January 1964.

Reliability estimates are continually changing due to revisions in the mission profile, changes in design and updated failure rate estimates. Since this report, estimates of subsystems and system reliabilities for a Hohman descent are being made. The weight-reliability study will include both design and mission profile changes in determining an overall optimum LEM system.

In light of the changes and the results of the weight-reliability study, it may be found necessary to reapportion the equipment reliabilities.

1.2 Summary

The current estimates for the probability for mission success and crew safety are shown in Table 1.1. The Mission Success Reliability estimates by phase is shown in Table 1.3 by subsystem. Mission Success reliability by subsystem is shown in Table 1.4. Tables 1.3 and 1.4 indicate the percent contribution to unreliability of the LEM system of each subsystem.

The increase in reliability over the previous quarter estimate is attributable to the better understanding of the reliability estimates submitted by MIT. Changes in mission plan due to the Mission Planning Task study have not as yet been incorporated into the reliability estimates.

Improvement in the overall Guidance and Navigation Function may still be forthcoming when the mission profile is resolved with MIT. This action will be accomplished this next quarter in order that Grumman and MIT reliability estimates can be based on the same mission phases and operational modes.

It can be seen that the first phase (pre-seperation), Table 1.1, has the lowest mission success probability. This results from the fact that the pre-seperation phase is the longest single phase in respect to time and the full phase operation of the electrical power and environmental control subsystem is required. The next largest contributor to mission success unreliability is the synchronous orbit phase. The primary contributors to unreliability in this phase are the Navigation and Guidance Function and the Propulsion subsystem, which each have relatively high probabilities of failure due to the length of the phase time and the present abort ground rules.

1.2.1 The Reliability Status of the major Grumman subcontractors is shown in Table 1.2.1.

TABLE 1.1

SUMMARY OF LEM MISSION SUCCESS AND CREW SAFETY ESTIMATES

	APPORTIONMENT	RELIABILITY ESTIMATE	
		Last Quarter	4th Quarter
MISSION SUCCESS	0.984	.868645	0.908
CREW SAFETY	0.9995	.980296	0.9844

MISSION SUCCESS RELIABILITY

TABLE 1.2

Subsystem	Pre-Sep.	Sep. To Insertion	Coasting Orbit To 50,000Ft	Powered Descent To 1,000Ft	Powered Descent From 1,000Ft To Landing	Lunar Stay For 4 Hrs	Lift Off Thru Injection	Transfer Orbit	Randezvous & Docking	Estimate	Apportionment
S & C	.999712	.999953	.999580	.999946	.999952	.999737	.998754	.998925	.999263	.995830	.9986005
N & G Function	.996892	.994381	.993546	.999208	.999534	.999057	.999473	.999201	.999324	.980760	.992183
ECS	.988081	.999966	.999469	.999797	.999932	.999188	.999904	.999909	.999917	.986186	.999446
EPS	.985976	.999632	.999350	.999778	.999927	.999352	.999882	.999883	.999928	.983741	.997776
Communications	.999471	.999974	.999339	-	-	-	-	-	-	.998784	.999918
Instrumentations	*	*	*	*	*	-	-	-	-	.998843+	.998843
Structure	**	**	**	**	**	**	**	**	**	.999945+	.999945
Descent Propulsion	.994457	.99942	.99067	.99479	.99811	-	-	-	-	.977875	.999075
Ascent Propulsion	.997468	.999995	.999927	.999973	.999991	.989632	.997643	.999999	-	.984686	.999961
RCS	.999699	.999901	.998514	.999408	.999997	.999975	.999954	.999952	.999966	.997368	.999804
LEM System	.962400	.993234	.980543	.993016	.997448	.986971	.995616	.997871	.998398	.907755	.984

* - Mission Success probabilities are not presently available due to a lack of design information about large portions of this subsystem.

** - Sufficient data is not available to allow a prediction of mission success probabilities for several of the subsystem components.

\+ The apportioned mission success reliability value is used in lieu of an estimated value for this subsystem

TABLE 1.2.1

RELIABILITY STATUS OF VENDORS

Vendors Currently Under Contract

Vendor	Equipment	Contract Date	Reliability Program Plan			Reliability Status Report		
			Due Date	Status	Date	Due Date	Status	Date
Rocketdyne	Descent Engine	5-1-63	7-1-63	Accepted	1-24-64	7-1-63	Accepted R-5226-2	1-22-64
STL	Descent Engine	7-3-63	9-3-63	Rejected	8-3-63	10-3-63	Rejected	9-3-63
Bell	Ascent Engine	7-3-63	9-3-63	Rejected 8258-910002	9-16-63	10-3-63	8258-932003	11-27-63
Marquardt	RCS Thrust Chambers	7-22-63	9-22-63	Rejected L1006	11-5-63	1-7-64	Being Reviewed	
Hamilton Standard	Environmental Cont. Subsys.	7-23-63	9-23-63	Program Plan Rejected	12-4-63	10-23-63	SV HSER 2807 Rejected	12-10-63
Radiation *	PCM and TC	12-3-63	1-18-64	Not Rec'd See Remarks		1-20-64		
Pratt & Whitney	Fuel Cell Ass'y	9-5-63	11-5-63	PWA 2406 Rev. A Rejected	1-7-64	12-5-63	Not Received	
RCA	Rendezvous and Landing Radar	11-7-63	12-7-63	Program Plan Accepted Provisionally	1-8-64	2-7-64		
Allison	Descent Tanks	12-11-63	1-11-64	Data Mgmt.		3-11-64		
Beckman	Digital & Analog	12-13-63	No Info					

* An Extension of 15 Days Was Given to Include the TE Report.

CRUW SAFETY RELIABILITY

TABLE 1.3

Subsystem	Crew Safety Estimate	% Cont. to Unreliability of LEM System
Propulsion Function	.9943	36.5
Stab. and Cont.	.9966	21.8
ECS	.9968	20.5
N and G Function	.9971	18.6
EPS	.9997	1.9
RCS	.9999	.6
Structures	.9999**	.6
Communications	*	

* Included in Navigation and Guidance

** The apportioned crew safety reliability value is used in lieu of an estimated value for this sybsystem.

TABLE 1.4

Mission Success Reliability

Subsystem	Mission Success Estimate	% Cont. to Unreliability of LEM System
Descent Propulsion	.977875	23.99
N & G Function	.980760	20.86
EPS	.983741	17.63
Ascent Propulsion	.984686	16.60
ECS	.986186	14.98
S & C	.995830	4.52
RCS	.997368	2.96
Communications	.998784	1.43
Instrumentations	.998843	1.36
Structure	.999945	.06

2. RELIABILITY MANAGEMENT AND CONTROLS

2.1 There have been no changes in management and/or controls since the last Quarterly Report.

3. SYSTEMS ANALYSIS

3.1 General

The major effort and accomplishments during the last quarter described in this report have been:

1. The completion of a computer program which gives lower bound reliabilities for a subsystem or system based on equipment success paths.

2. A study which relates system functions and equipments by phase is near completion.

3. The first phase report of the weight-reliability study will be published within the next quarter and a summary will be presented in the next Quarterly Report.

One of the major efforts under way is the compilation of all subsystem reliability success paths by phase. These paths will be used to estimate system reliability, perform contingency analyses, to determine the interactions between subsystems, to perform critical load analysis for the EPS, and will be used in any reapportionment.

3.2 Reliability Estimation

Mission success and crew safety probabilities were calculated on a conditional basis. Discussion is presented below incating some of the considerations and implications of using conditional probabilities. In order to facilitate these computations, a computer program (described below) has been employed.

3.2.1 Mission Success

The current estimates for the probability of mission success for the nominal LEM vehicle are presented in Table 1.2. These estimates represent the mission success probabilities as of 15 December 1963 and are computed on the basis of a mission comprised of the phases listed in Table 1.2. These phases include a full synchronous orbit prior to descent and a four hour lunar stay during which one man is required to set foot on the lunar surface and collect specimens. The LEM is then required to lift off, complete a successful rendezvous, dock with the CSM, and permit the safe transfer of both astronauts from the LEM to the CSM. The phase and total mission success estimates for each subsystem were calculated as conditional probabilities, i.e., probability of successfully completing some specified mission phase assuming that all previous mission phases had been successfully completed. The probability of mission success for a subsystem is therefore calculated as the probability of the subsystem sucessfully completing the rendezvous and docking phase given that it has successfully completed all mission phases from pre-separation through transfer orbit. A discussion of the formulas used in calculating these probabilities is presented in the crew safety section (Section 3.2.2).

In estimating the mission success probability for several of the subsystems, special problems were encountered. For example, the probabilities associated with descent propulsion were computed based upon GAEC estimates of a composite of the Rocketdyne and STL engines. The GAEC estimates provided a mission success estimate which was between the estimates submitted by STL and Rocketdyne (see Propulsion Section). The ascent engine estimates are also GAEC estimates.

Phase estimates for the instrumentation subsystem and structures were not available by the present cut-off date. The reason for the absence of the instrumentation subsystem estimates was the lack of design definition for major portions of the subsystem. The absence of the structures estimates was due to the lack of sufficient information necessary to estimate the mission success probability for several subsystem components. The apportioned values of mission success were therefore used in lieu of any mission success estimates for these subsystems. The navigation and guidance function estimates pertain to the primary navigation and guidance system, the back-up guidance system, and the radars. It appeared unreasonable to separate the back-up system from the primary system in calculating the mission success and crew safety probabilities.

As a result of the unavailability of estimates for some of the above mentioned subsystems, the phase estimates (Table 1.2) for the total system only represent eight of the ten LEM subsystems. However, it is not expected that the inclusion of estimates for the other two subsystems will alter the relative magnitudes of the phase estimates.

3.2.2 Crew Safety

"Crew Safety Probability" is a number indicating the probability that a given system operating under a defined set of ground rules will function in such a manner that no crew catastrophe will occur resulting from failures in the given system. The ground rules specify the conditions of the system that will require the mission to be continued, altered, or aborted.

3.2.2 (continued)

Crew safety will be calculated from the basic mathematical model of mission success paths of equipment which are defined for each mission phase. Certain paths will have feasibility numbers (see paragraph 3.3.5) associated with them which indicate the probability that the given path will be successful in the indicated phase, assuming that the equipments are operating. Using this mathematical model, the following statements will hold:

1. In each phase an abort condition will have been reached if and only if all mission success paths have failed or an abort situation associated with a feasibility factor contingency has been reached. Under such circumstances crew safety will occur if and only if one of the abort paths available from the phase remains operative for the time required to accomplish rendezvous and docking with the CSM. The time used for the abort period will be the longest time required to abort the mission from any point in the phase under consideration.

2. The time period used for the lunar stay phase will be 23 hours.

3. The formula which gives the crew safety probability as well as an approximating formula (for either a subsystem or over-all system) may be described using the following notation:

   $R(M)$ = The probability of mission success. This value, if properly computed, should account for the fact that not every equipment path in a phase will be open by the time the phase is reached. It is necessary that $R(M)$ be calculated on a conditional basis.

   $R_i^c(M)$= The probability of successfully completing the mission requirements of the i^{th} phase, assuming mission success in the previous phases. This number takes into consideration the fact that previous equipment failures may have eliminated certain reliability paths for the i^{th} phase, even though there was mission success in the previous phases.

$$R(M) = \prod_{i=1}^{n} R_i^c(M)$$

   where n phases are considered as constituting the full mission.

3.2.2 (continued)

$R_i(M)$= The probability of successfully completing the mission requirements of the i^{th} phase <u>assuming</u> that all equipments and paths are available at the start of the phase. It should be noted that for a particular phase $R_i(M) = R_i^c(M)$ if and only if, in all previous phases there was only a single series success path or if the equipments required in the i^{th} phase have not been previously used.

$R_i^x(M)$= The probability of successfully completing the mission requirements from the start of the mission to the end of the i^{th} phase. Then:

$$R_i^x(M) = \prod_{j=1}^{i} R_j^c(M) \quad \text{and} \quad R(M) = R_n^x(M)$$

$P_i^c(A)$= The probability of successfully aborting and completing rendezvous after having mission success through the first i-1 phases and a failure situation occurring in the i^{th} phase which the ground rules specify as an abort situation. If the failure is itself a catastrophic failure, there will be no positive contribution to $P_i^c(A)$.

$Q_i(M)$= $1 - R_i(M)$

$Q_i^c(M)$= $1 - R_i^c(M)$

$R(S)$ = The probability of Crew Safety for the entire mission. Then,

$$R(S) = R(M) + \sum_{i=1}^{n} R_{i-1}^{x}(M) \cdot Q_i^c(M) \cdot P_i^c(A)$$

This formula states that Crew Safety Probability equals Mission Success Probability plus the probability that in one of the n phases an abort situation develops after having had mission success through the previous phases and that successful rendezvous with the CSM is accomplished from the abort phase. This formula describes the method that will be used to calculate crew safety whenever possible for any subsystem or for the entire LEM system. Thus, this formula sums the probabilities of all the different contingencies which result in crew safety.

3.2.2 (continued)

In most situations, it will be difficult to calculate the term $P_i^c(A)$ because it may be that the equipment failures which caused the abort situation to occur also may have rendered it impossible to rendezvous using certain sets of equipment. That is, only a certain number of the previously available methods of achieving rendezvous may be available for use at the time the abort is begun. Since it is not known which failures caused the abort situation it is not know which sets of equipment (if any) are available for attempting rendezvous. Thus, in order to calculate $P_i^c(A)$ all possible combinations of equipment failures, which resulted in an abort situation, would have to be considered. In general, this is not very feasible. Therefore, either an approximation to this term must be made or else the following alternative lower bound approximation formula to crew safety can be used: Let M_i be the event that the system operates so that mission success in the i^{th} phase can be accomplished. Also, let CS_i be the event that the system operates so that an abort can be successfully achieved from any point in the i^{th} phase. These events are unconditional in that they are not predicated upon any knowledge of events in the previous phases. Then,

$$\bigcap_{i=1}^{N} (M_i \cup CS_i) \longrightarrow \text{Crew Safety}$$

That is, having the capability for either mission success or for successfully aborting in every phase implies that crew safety occurred. Therefore,

$$P\left(\bigcap_{i=1}^{N} (M_i \cup CS_i)\right) \leq R(S)$$

Also,

$$\prod_{i=1}^{N} P(M_i \cup CS_i) \leq P\left(\bigcap_{i=1}^{N} (M_i \cup CS_i)\right)$$

since the right-hand side of the last inequality should theoretically be calculated on a conditional basis. Therefore,

$$\prod_{i=1}^{N} P(M_i \cup CS_i) \leq R(S)$$

Each of the terms in the above product can be calculated by the Reliability Estimation Computer Program. Therefore, in most situations the use of this formula in conjunction with the program will be the most practical method of estimating crew safety.

3.2.2 (continued)

Table 1.3 contains the crew safety estimates for the nominal LEM vehicle as of 15 December 1963.

It should be noted that an estimate was made for the navigation and guidance function rather than the subsystem since it was felt unreasonable to estimate separately the primary and back-up systems.

The propulsion function was also estimated because of the role the ascent system plays in backing-up the descent system for aborts.

3.2.3 Lower Bound Reliability Computer Program

The Lower Bound Reliability Evaluation Computer Program has been completed and checked out. This program has the capability of deriving a lower bound reliability to any system configuration operating through a maximum of twenty phases. The success paths (see LER-550-3) in each phase and the reliability of each equipment in each phase are used as inputs to the program. The program will find and print out the minimal failure paths (see LER-550-3) for each phase relative to that phase. After it has found the minimal failure paths for each of the phases, it will proceed to find the minimal failure paths relative to the over-all mission. This means that any failure path in a lower phase, which contains, as a subset, a failure path in some higher phase, will be eliminated. The remaining minimal failure paths represent all the different conditions which would cause the system to fail. These mission minimal failure paths and their associated phases will also be printed out. Finally, a mission lower bound reliability, derived from these mission minimal failure paths, will be computed and printed out. The program has the capability to run consecutively an arbitrary number of configurations with an arbitrary number of reliability input sets for each configuration. Thus, it is possible to run various parametric studies all in one computer run.

There are three basic types of parametric studies for which this program will be used. The first type consists of varying the ground rules under which a given system will be allowed to operate. Varying the failure conditions, which constitute grounds for aborting the mission, will yield mission success and crew safety numbers corresponding to each set of ground rules. In this manner, an abort philosophy, which represents the best trade-off between mission success and crew safety, can be evolved. Another basic type of trade-off involves varying the failure rate of a given piece of equipment to see how sensitive mission success and crew safety are to the failure rate of that equipment for a given design configuration using a given set of ground rules. This type of analysis can isolate those equipments to which mission success or crew safety is most sensitive under the given ground rules. The third basic type of trade-off involves varying the design configuration of a given system keeping the reliability of the individual equipments in the system constant and keeping the ground rules as similar as possible for each configuration. These parametric studies should eventually combine into an over-all optimization between ground rules, equipment reliabilities, and design configurations.

3.3 System Status

During the last quarter, it was decided to develop a convenient means of representing equipment-function relationships in order to facilitate performing contingency analyses. This representation or format was intended to be a focal point in the determination of decision intervals and also to permit specifying mission success paths for evaluation by a computer program. The approach to be used in LEM Contingency Analysis is discussed in LMO-540-188.

3.3.1 Equipment-Function Relationship

The primary effort during the last quarter has been to develop a format by which system functions can be related to various equipments for each phase considered.

The format has a set of indicator codes associated with it for relating the equipments and functions (Table 3.3.2). The format will also permit contingency analyses to be performed by using a different set of indicator codes which have not yet been defined.

Fifteen functions and thirty-six equipment groups were defined for an initial pass at setting up the format for equipment-function relationships. Equipment groups refer to system, subsystem, assembly, or sub-assembly call out such that each group can be independently associated with the various functions. Tables 3.3.3 and 3.3.4 list the equipment groups and functions used for the first two phases. Most of the equipment groups require no explanation. Two equipment groups, numbers 24 and 25, require further description. Group 24, Crew-Functions Equipment, includes such items as crew couches, food-management equipment, waste-management equipment, etc.. Group 25, Data-Collection Equipment, includes such items as photographic equipment, scientific instrumentation, television equipment, etc..

In specifying the mission functions the following criteria was used as a basis: (1) the functions should be independent of one another, (2) the mission, phase-by-phase, should be completely describable by logical combinations of the functions, (3) the functions should not require any equipment breakdown beyond the sub-assembly level.

3.3.1 (continued)

The functions selected are listed in Table 3.3.2. In selecting the functions, it was necessary to compromise the first criterion in order to comply with the third criterion. In a general way, the computation functions could be considered as subsets of the control functions. However, specifying the control functions only would not permit listing the alternate modes of performing the various functions. With this capability lost, the developed format would provide limited service for its intended purpose.

The first four functions in Table 3.3.2 refer to the measurements taken and the computations performed to permit a decision to be made. This decision could be made by manual or automatic means. The ranging function is intended to include the operations of the landing and rendezvous radars, and also to cover other functions as providing for mid-course corrections and selecting a landing site. The control functions (attitude, translation, and large thrust) refer to all modes of control (e.g., developing torques), manual, semi-automatic, or automatic. These include modes such as the attitude hold mode, the rate command mode, the attitude command mode, the direct attitude mode, the translation mode, etc..

The LEM/LEM communication function refers to communication between the two astronauts on the LEM. The LEM/CM communication function refers to communication between either (or both) of the astronauts on the LEM and the astronaut in the Command Module. The LEM/MOON communication function refers to the communication between one astronaut in the LEM (while the LEM is on the lunar surface) and the other astronaut who is outside the LEM exploring the lunar surface. The LEM/EARTH communication function refers to communication between the LEM and GOSS. This includes transmission of voice and monitored data.

The last three functions require clarification so as to be distinguished from one another. Monitoring relates to determining the status of equipments as they affect crew safety and mission success. Scientific data collection refers to the performance of various lunar exploration tasks (e.g., sample collection, photographs, etc.). Other data collection tasks fall into the monitoring category. The crew necessities task comprises a multitude of functions such as crew support, restraint, protection, atmosphere control, hygiene, food, waste management, etc.. These tasks relate to maintaining the crew's physical and mental abilities for the performance of the many manual and semi-automatic functions.

3.3.1 (continued)

Fourteen phases are being considered for the nominal mission. These are listed in Table 3.3.1. The relationships between the functions and equipment groups have been completed for the first two phases and are shown in Tables 3.3.3 and 3.3.4. The interpretation of the codes used is as follows:

Code	Meaning
0	The equipment is not needed to perform the function in this or any future phase.
1	The equipment is necessary for the performance of the function, but only in a later phase (either primary or alternate).
2	The equipment is necessary for the performance of the function.
3	The equipment can be used as back-up for all or part of the function in this phase.

It should be noted that code (state) 3 has priority over code (state) 1 in relating functions and equipments.

Several equipment groups perform service functions to the list of functions used here. As a result these equipment groups were associated with the many functions they service rather than call out the service functions separately. For example, the Electrical Power System (EPS) services most of the listed functions and has been related to these functions in the charts. The Environmental Control System (ECS) was also associated with the many functions it services. In contrast, such equipment groups as the Inertial Measurement Unit (IMU) and the Attitude and Translational Control Assembly (ATCA) perform listed functions and are associated with fewer functions.

3.3.2 Decision Intervals

The original ten phases, defined as decision intervlas in the last quarterly report, have been redefined and extended to fourteen phases or decision intervals. These fourteen phases were defined (see Table 3.3.1) since it was felt that the equipments required for various functions changed with the phases.

It was felt that these phases would suffice for the development of the format in Section 3.3.1. Many decisions and, hence, the decision intervals are defined for those equipments and functions which are not related (code-0), namely, continue the mission.

3.3.3 Contingency Analysis

As mentioned before, the developed format will also be used to perform contingency analyses. The analyses will include:

(1) Where possible, contingency phases will be defined for the purpose of determing equipment-function relationships for the possible contingency decisions. The contingency decisions (defined in the previous quarterly report) include:

(a) continue the planned mission
(b) abort
(c) delay and/or repair
(d) go into an alternate mission plan where (c) could be considered as being this contingency decision, if necessary.

(2) A multiple equipment failure effect analysis will be performed in terms of a functional failure effects analysis. In this way, only meaningful combinations of equipments will be considered. The above decisions will be encoded for use in the format.

3.3.4 Path Determination

One of the purposes for the development of such a format for relating functions and equipments is to be able to call out mission success paths for all phases for use with and evaluation by the "Lower Bound Reliability Program" (see Section 3.3.5). Many other applications are anticipated. They include:

(a) evaluation of contingencies
(b) ranking and determination of critical equipment groups
(c) performing trade-off studies such as delta V versus reliability
(d) determining optimal decision intervals.

TABLE 3.3.1

NOMINAL DECISION INTERVALS

1	Separation Up To Insertion
2	Insertion Into Descent Transfer Orbit
3	Coasting Orbit To 50,000 Foot Pericynthion
4	Initial Power Descent To 20 Nautical Miles From Landing Site
5	Final Powered Descent To Hover (1000 Feet From Lunar Surface)
6	Hover To Touchdown
7	Lunar Stay (Post Landing Checkout)
8	Lunar Stay (Exploration)
9	Lunar Stay (Pre-Launch Checkout)
10	Powered Ascent
11	Insertion Into Free-Flight Transfer Orbit
12	Coast In Orbit To 20 Nautical Miles From CSM
13	Rendezvous From 20 Nautical Miles To 500 Feet From CSM
14	Rendezvous From 500 Feet To Docking With CSM

TABLE 3.3.2

MISSION FUNCTIONS

1	Inertial Attitude Determination
2	Inertial Position Determination
3	Inertial Velocity Determination
4	Delta Velocity Determination
5	Ranging
6	Attitude Control
7	Translation Control
8	Large Thrust Control
9	LEM/LEM Communication
10	LEM/CSM Communication
11	LEM/MOON Communication
12	LEM/EARTH Communication
13	Monitoring
14	Scientific Data Collection
15	Crew Necessities

TABLE 3.3.3

PHASE 1 SEPARATION UP TO INSERTION — FUNCTION / EQUIPMENT GROUP	LANDING RADAR #1	RENDEZVOUS RADAR #2	INERTIAL MEAS. UNIT & PWR. SERVO ASS'Y #3	LEM GUIDANCE COMPUTER #4	COUPLING DISPLAY UNITS FOR IMU #5	RADAR DISPLAYS #6	ALIGNMENT OPTICAL TELESCOPE #7	SIGHTING DEVICE #8	GUIDANCE COUPLER ASSEMBLY #9	ATTITUDE & TRANSLATIONAL COUPLER ASS'Y #10	RATE GYRO ASSEMBLY #11	DESCENT ENGINE CONTROL ASSEMBLY #12	ATTITUDE CONTROLLER #13	TRANSLATION CONTROLLER #14	INFLIGHT MONITOR ASSEMBLY (SAC) #15	REACTION CONTROL SYSTEM #16	EVENTS TIMERS (TIME TO-AND-FROM) #17	BACKUP GUIDANCE SYSTEM #18	PRE-MODULATION PROCESSOR #19	S-BAND #20	BACK PACK RCVR & XMTR #21	VHF (LESS PRE-MOD, PROC, & AUDIO CENTER) #22	INTERCOM #23	CREW FUNCTION EQUIPMENT #24	DATA COLLECTION EQUIPMENT #25	SENSORS & SIGNAL CONDITIONERS #26	PULSE CODE MODULATION & TDMIN EQUIPMENT #27	ON-BOARD CHECKOUT EQUIPMENT #28	CAUTION & WARNING DISPLAY SYSTEM #29	STRUCTURAL SYSTEM #30	DESCENT PROPULSION SYSTEM #31	ASCENT PROPULSION SYSTEM #32	ELECTRICAL POWER SYSTEM #33	AUDIO CENTERS #34	ENVIRONMENTAL CONTROL SYSTEM #35	PYROTECHNICS SYSTEM #36
INERTIAL ATTITUDE DETERMINATION #1			2	2	2		1											1															2		2	
INERTIAL POSITION DETERMINATION #2			2	2			1											1															2		2	
INERTIAL VELOCITY DETERMINATION #3			2	2			1											1															2		2	
DELTA VELOCITY DETERMINATION #4			2	2			1											1															2		2	
RANGING #5	1	1		1		1		1																									2		2	
ATTITUDE CONTROL #6			2						2	2	2	1	1			2		1													1		2		2	1
TRANSLATION CONTROL #7									2	2	2			1		2																	2		2	1
LARGE THRUST CONTROL #8									1			1																			1	1	2		2	1
LEM/LEM COMMUNICATION #9																			2				2										2	2	2	
LEM/CM COMMUNICATION #10																			2			2											2	2	2	
LEM/MOON COMMUNICATION #11																			1		1	1											1	1	1	
LEM/EARTH COMMUNICATION #12																			2	2													2	3	2	
MONITORING #13															2		1									2	2	2	2				2		2	
SCIENTIFIC DATA COLLECTION #14																									1	1	1						1		1	
CREW NECESSITIES #15																								2						2			2		2	

NOTE: CODE "0" OF SECTION 3.3.1 IS REPRESENTED BY AN EMPTY CELL

TABLE 3.3.4

PHASE 2 INSERTION INTO DESCENT TRANSFER ORBIT — FUNCTION / EQUIPMENT GROUP	LANDING RADAR #1	RENDEZVOUS RADAR #2	INERTIAL MEAS. UNIT & PWR. SERVO ASS'Y #3	LEM GUIDANCE COMPUTER #4	COUPLING DISPLAY UNITS FOR IMU #5	RADAR DISPLAYS #6	ALIGNMENT OPTICAL TELESCOPE #7	SIGHTING DEVICE #8	GUIDANCE COUPLER ASSEMBLY #9	ATTITUDE & TRANSLATIONAL COUPLER ASS'Y #10	RATE GYRO ASSEMBLY #11	DESCENT ENGINE CONTROL ASSEMBLY #12	ATTITUDE CONTROLLER #13	TRANSLATION CONTROLLER #14	INFLIGHT MONITOR ASSEMBLY (S&C) #15	REACTION CONTROL SYSTEM #16	EVENTS TIMERS (TIME TO-AND-FROM) #17	BACKUP GUIDANCE SYSTEM #18	PRE-MODULATION PROCESSOR #19	S-BAND #20	BACK PACK RCVR & XMTR #21	VHF (LESS PRE-MOD. PROC. & AUDIO CENTER) #22	INTERCOM #23	CREW FUNCTION EQUIPMENT #24	DATA COLLECTION EQUIPMENT #25	SENSORS & SIGNAL CONDITIONERS #26	PULSE CODE MODULATION & TIMING EQUIPMENT #27	ON-BOARD CHECKOUT EQUIPMENT #28	CAUTION & WARNING DISPLAY SYSTEM #29	STRUCTURAL SYSTEM #30	DESCENT PROPULSION SYSTEM #31	ASCENT PROPULSION SYSTEM #32	ELECTRICAL POWER SYSTEM #33	AUDIO CENTERS #34	ENVIRONMENTAL CONTROL SYSTEM #35	PYROTECHNICS SYSTEM #36
INERTIAL ATTITUDE DETERMINATION #1			2	2	2		1											1															2		2	
INERTIAL POSITION DETERMINATION #2			2	2			1											1															2		2	
INERTIAL VELOCITY DETERMINATION #3			2	2			1											1															2		2	
DELTA VELOCITY DETERMINATION #4			2	2			1											1															2		2	
RANGING #5	1	1		1		1		1																									2		2	
ATTITUDE CONTROL #6			2						2	2	2	2	1			2		1													2		2		2	1
TRANSLATION CONTROL #7									2	2	2			1		2																	2		2	1
LARGE THRUST CONTROL #8									1			2																			2	1	2		2	1
LEM/LEM COMMUNICATION #9																			2				2										2	2	2	
LEM/CM COMMUNICATION #10																			2			2											2	2	2	
LEM/MOON COMMUNICATION #11																			1		1	1											1	1	1	
LEM/EARTH COMMUNICATION #12																			2	2													2	3	2	
MONITORING #13															2		1									2	2	2	2				2		2	
SCIENTIFIC DATA COLLECTION #14																									1	1	1						1		1	
CREW NECESSITIES #15																								2						2			2		2	

NOTE: CODE "0" OF SECTION 3.3.1 IS REPRESENTED BY AN EMPTY CELL

3.3.5 Equipment Path Feasibility Studies

In the event that certain equipments fail at a given point in the mission, it may be necessary to perform certain vital functions with an alternate set of equipments. Whether or not an affirmative decision to continue the mission is made will depend partially on how well the remaining equipments can perform the remaining functions of the mission. Thus, it becomes necessary to evaluate the capability of various sets of equipments operating in unison to perform a certain function(s). The possible degradations to the system, which may result from using an alternate set of equipments, may involve: a loss of accuracy in the function, an extension of the mission time, greater fuel consumption of the main engines and/or reaction control subsystem, greater enpenditure of other consumable such as life support equipment, etc.. In addition, other equipments needed to complete the mission must function for the extended mission time. Another degradation consideration is the time available to execute the required maneuvers using the available equipments. Similarily, there may be degradation of mission performance directly attributable to a manual mode of operation. This factor is proportional to the number of complexity of the manual operations required of the astronaut by the failure of the automatic mode of operation.

The important alternate equipment sets will have to be evaluated individually to ascertain in a probabilistic form the extent of degradation in relation to the remaining requirements of the mission. This may require an error analysis involving the combination of random variables from different distributions. The feasibility factors derived from such studies will be incorporated into the overall reliability estimation program and the studies derived from it.

Information from the Full Mission Engineering Simulator should help determine whether certain combinations of equipments can interface satisfactorily as far as the electrical signal interactions are concerned. This information should be useful in determining the accuracy of information or degree of performance to be expected from the use of a particular path. The expected performance must be considered in relation to requirements in determining a feasibility factor for the path. Also, the deletion or possible addition of paths, based on the results of the FMES, should enhance reliability estimates.

3.4 Weight-Reliability Study

During the early phases of the LEM Program, subsystem target weights and reliability apportionments were generated independently. These independent approaches lead to several inconsistencies. Weight apportionments were obtained by scaling down estimated subsystem weights to meet the LEM separation weight goal of 26,000 pounds.

The reliability apportionments were obtained by scaling up the estimated subsystem reliabilities to meet the goals of 0.984 for mission success and 0.9995 for crew safety. The major problem in apportioning weight and reliability in this way is that to meet weight goals, reliability would have to be reduced, and to satisfy reliability goals, weight would have to be increased, as, for example, by redundancy.

The objective of the LEM weight and reliability optimization studies was to aid in the definition of a LEM vehicle which represents a "reasonable balanace" between system reliability and effective weight. The term "reasonable balance" is used since it does not seem likely at this time that the stated mission success, .984, and crew safety, .9995, probability goals can be met within the target weight constraint using currently available equipment failure rates.

Implementation of the weight-reliability study was carried out using the following format. A "nominal" LEM vehicle, composed of "nominal" subsystems, approved by the weight-reliability panel, served as the based for the Weight-Reliability Analysis. At least four (4) alternate subsystem configurations were defined by the cognizant subsystem engineer in conjunction with the subsystem reliability engineer; not all of these configurations were either all heavier or all lighter than the "nominal" subsystem configuration. A Maximum Mission Success Vehicle, a Maximum Crew Safety Vehicle, a Minimum Weight Vehicle, and an Optimum Vehicle will be derived from these configurations.

At the present time detailed studies are being carried out in the following areas in an attempt to arrive at this "reasonable balance": subsystem weight-reliability trade-offs; analysis of alternate mission profiles, i.e., Hohmann Descent Orbit instead of Synchronous Descent Orbit; subsystem utilization studies including variations in the use of EPS, ECS, and Ascent Propulsion Subsystems. It is anticipated that a detailed report will be published during the next quarter indicating the results of this Weight-Reliability effort. Table 3.4 is a complete listing of the subsystem weights and reliabilities used in this study and estimated for a nominal mission, including a $1\frac{1}{4}$ synchronous orbit in descent.

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Note:
(a) = weight of items which were significant in the reliability analysis
(b) = weight of items which were not significant in the reliability analysis

TABLE 3.4

WEIGHT-RELIABILITY STUDY BY SUBSYSTEMS

Subsystem	"Nominal" Configuration No. 1					Configuration No. 2					Configuration No. 3					Configuration No. 4					Configuration No. 5				
	Weight			Reliability		Weight			Reliability		Weight			Reliability		Weight			Reliability		Weight			Reliability	
	Un-Staged	Staged	Total	C.S.	M.S.	Un-Staged	Staged	Total	C.S.	M.S.	Un-Staged	Staged	Total	C.S.	M.S.	Un-Staged	Staged	Total	C.S.	M.S.	Un-Staged	Staged	Total	C.S.	M.S.
1. Structure (a)																									
(b)	884.8	802.0	1686.8																						
Total	884.8	802.0	1686.8																						
2. Crew Provisions (a)	413.2		413.2																						
(b)	147.6	10.6	158.2																						
Total	560.8	10.6	571.4																						
3. Landing Gear (a)																									
(b)		468.0	468.0																						
Total		468.0	468.0																						
4. Instrumentation (a)																									
(b)	387.9	200.0	587.9																						
Total	387.9	200.0	587.9																						
5. Displays And Controls (a)																									
(b)	179.8	-	179.8																						
Total	179.8	-	179.8																						
6. Nav. and Guid.				.997095	.980760																				
7. Propulsion (Eng. & Plumb. only) (a)	229.1	467.9	697.0	.994283	.962901	230.7	472.3	703.0	.994107	.950642															
(b)																									
Total	229.1	467.9	697.0			230.7	472.3	703.0																	
8. Stab. and Control (a)	49.6	13.5	63.1	.996638	.995830	49.6	7.5	57.1	.996628	.995750	33.8	7.5	41.3	.987288	.983830	72.6	13.5	86.1	.999925	.999882					
(b)	10.0	-	10.0			10.0	-	10.0			10.0	-	10.0			10.0	-	10.0							
Total	59.6	13.5	73.1			59.6	7.5	67.0			43.8	7.5	51.3			82.6	13.5	96.1							
9. El.Pwr.Gen. (inc. dist. batt.) (a)	440.6	82.6	523.2	.999952	.991123	372.0	82.6	454.6	.999985	.990700	381.2	77.7	458.9	.999994	.990765	353.4	76.8	430.2	.999995	.989452	300.4	77.7	378.1	.999999	.974984
(b)	31.0	87.0	118.0			31.0	87.0	118.0			31.0	87.0	118.0			31.0	87.0	118.0			31.0	87.0	118.0		
Total	471.6	169.6	641.2			403.0	169.6	572.6			412.2	164.7	576.9			384.4	163.8	548.2			331.4	164.7	496.1		
10. El.Pwr.Conv. (inc. wire) (a)	56.1	-	56.1	.999413	.993419	56.6	-	56.6	.999703	.993686	48.4	-	48.4	.999703	.994230	81.0	-	81.0	.999972	.999857	97.4	-	97.4	.999962	.999842
(b)	373.0	35.0	408.0			373.0	35.0	408.0			373.0	35.0	408.0			373.0	35.0	408.0			373.0	35.0	408.0		
Total	429.1	35.0	464.1			429.6	35.0	464.6			421.4	35.0	456.4			454.0	35.0	489.0			470.4	35.0	505.4		
11. Reaction Control (a)	308.6	-	308.6	.999870	.997385	290.8	-	290.8	.999863	.997328	250.5	-	250.5	.999172	.996567	299.7	-	299.7	.999871	.997386	238.8	-	238.8	.997949	.990780
(b)	238.0	54.0	292.0			238.0	54.0	292.0			238.0	54.0	292.0			238.0	54.0	292.0			238.0	54.0	292.0		
Total	546.6	54.0	600.6			528.8	54.0	582.8			488.5	54.0	542.5			537.7	54.0	591.7			476.8	54.0	530.8		
12. Communication (a)	37.3	- -	37.3		.998784	27.3	10.0	37.3		.998784	41.7	-	41.7		.999180	31.7	10.0	41.7		.999180	31.7	10.0	41.7		.999180
(b)	46.0	28.0	74.0				59.0	59.0			46.0	28.0	74.0				59.0	59.0				65.0	65.0		
Total	83.3	28.0	111.3			27.3	69.0	96.3			87.7	28.0	115.7			31.7	69.0	100.7			31.7	75.0	106.7		
13. Environ. Control (a)	193.3	-	193.3	.996775	.986187	159.8	20.7	180.5	.999518	.973977	177.7	18.2	195.9	.999693	.982659	190.5	18.2	208.7	.999681	.982174	225.0	.2	225.2	.999731	.984415
(b)	197.9	138.7	336.6			192.6	138.7	331.3			172.6	108.7	281.3			177.5	103.8	281.3			207.5	103.8	311.3		
Total	391.2	138.7	529.9			352.4	159.4	511.8			350.3	126.9	477.2			368.0	122.0	490.0			432.5	104.0	536.5		

3.4 (continued)

Future efforts will include close coordination with the Apollo Mission Planning Group in deriving alternate mission profiles and analyzing the LEM-CSM interface. Continued updating of weight and reliability estimates as well as the evaluation of new subsystem and system configurations will also be carried on.

3.5 Reliability Control Programs

The over-all concept of the Reliability Control Programs is developing in line with the previous quarterly reports. The programs comprise a data gathering and retrieval system for the incorporation of automatic data processing techniques in the areas of parts control, failure reporting and test identification. An integration effort is being studied to insure maximum interface with all three programs. In addition, a special effort is currently being pursued in the areas of implementation, training, operating procedures, and program modifications. Special emphasis on a system basis will be considered during this phase to insure compatibility of reporting formats, data flow, and data control functions.

Phase one engineering delineation effort is essentially complete. Minor changes in item description or content will be considered provided such changes do not require significant alterations or additions to the current programming effort. Changes affecting major logic redesign or copious coding assignments will be delayed for consideration at the conclusion of the debugging effort. These changes will then be re-examined and evaluated for inclusion into the program.

3.5.1 General Accomplishments

The principal effort of this quarter has been threefold: completion of the phase one definition effort, finalizing of the detailed logic design followed by implementation of the coding assignments. A second task associated with the latter was the preparation of sample parts data to be utilized in the computer debugging effort. A preliminary LEM Radar configuration was selected from which data was extracted and translated into card format for basic part additions to the parts catalogue. In some instances this data was revised to exhibit a multiple of computer problems considered in the over-all programming effort. This data will be enlarged in volume and further modified to facilitate other transactions, such as part changes and deletions for the purpose of testing such computer transactions.

TABLE 3.5.1

LEM RELIABILITY COMPUTER PROGRAM

CURRENT DEVELOPMENT PLAN -- 1964

Program	February	March	April	May	June
Parts Control Program	1st Draft (Three Basic Outputs*)	GAEC Facility Program Check-out	Production Program Completed	Program and Procedures Documentation	
Failure Reporting Program	Complete Detailed Program Logic	1st Draft Complete	GAEC Facil-ity Program Checkout	Production Program Completed	Program and Procedures Documentation
Test Status Program	Complete Detailed Program Logic	1st Draft Complete	GAEC Facil-ity Program Checkout	Production Program Completed	Program and Procedures Documentation

* Three Basic Outputs:
(1) LEM Parts List
(2) Where-Used List (Two Levels)
(3) Top Down Break Down

NOTE: First Draft of Parts Control Program is Also Preliminary Evaluation of Program Design Feasibility

3.5.1 (continued)

A series of meetings were held with MSC officials to discuss contents of the NASA publication, "Contractor's Information Control Center Requirements", dated 25 October 1963.

Discussions centered on MSC's plan to establish an Apollo Data Center. Elements of the LEM Reliability Computer Program which would be applicable to the Apollo data bank also were examined. It was re-emphasized during these meetings that MSC plans will not impede the scheduled development of the LEM Reliability Computer Program.

3.5.2 <u>Detailed Progress</u>

The functional design of the Parts Control Program was completed. This design defines four computer sub-programs as follows:

(1) Pre-Processor
(2) Update
(3) Search and Extract
(4) Post Processor.

These sub-programs establish the framework for continued work on the Parts Control Program and the future incorporation of the failure reporting and test identification functions. This effort will also provide the necessary input formats for preparing input data that will checkout and demonstrate operation of the over-all computer program.

Coding has essentially been completed for the Pre-Processor. Debugging has progressed and is approximately 90 per cent complete.

Coding of the Update Program is also approximately 90 per cent complete and debugging is now in progress and about 80 per cent complete.

Coding of the Search Program is complete and debugging is 40 per cent complete.

Coding of the Post Processor is complete and debugging is 50 per cent complete.

3.5.2 (continued)

No further coding assignments have been implemented for the Test Identification or Failure Reporting Programs; however, over-all requirements were considered in the program design. Detailed programming and coding assignments for Test Identification and Failure Reporting Programs are scheduled during the next quarter. Debugging and implementation of the Parts Program will also continue during this period.

A failure reporting plan was completed containing instructions for preparation of a computer program designed for fast retrieval of failure data. This plan also contains an outline for acquisition, processing, and formating of data for use in the LEM Reliability Computer Program.

Table 3.5.1 shows the current LEM Reliability Computer Program plan.

4.1 PROPULSION SUBSYSTEMS

During this report period the Propulsion Subsystem Reliability Effort has been directed toward:

a. the monitoring of engine vendor reliability programs

b. the investigation of failure rates used in GAEC estimates of subsystem reliability

c. a comparative analysis of helium pressure regulators to be used in both the Reaction Control and main Propulsion Subsystems of LEM

d. a set of ground rules formulated for calculating subsystem reliability estimates for successive configurations

e. configuration studies of the ascent subsystem propellant tankage.

4.1.1 Propulsion Subsystem Reliability Programs

There have been no significant changes of subsystem reliability estimates or apportionments during this period. The latest available estimates (shown in Table 4.7.2) are the same as those which appear in the third Quarterly Reliability Status Report (Reference B) with the exception of the descent engine estimates. The descent engine estimates in this report reflect the respective vendor estimate.

Deletion of the requirement for operation during the transfer orbit, after ascent from the lunar surface, accounts for the revised reliability estimate of the ascent engine subsystem.

The apportioned reliabilities for both the ascent and descent engine subsystems previously reported (Reference B) have been revised to agree with the apportionments defined in the respective engine design control specifications (References E, F and G).

4.1.2 Engine Vendor Reliability

4.1.2.1 Ascent Engine - Bell Aerosystems Company

The Program Plan, including the Reliability Plan, (Reference H) submitted by Bell Aerosystems Company, has not

4.1.2.1 (continued)

yet been approved by GAEC. Comments regarding this document were sent to BAC listing the revisions required prior to acceptance, (Reference J). Receipt of the comments has been acknowledged by BAC and revision of the Program Plan is in process.

During this report period the engine mission operating requirements were redefined to clarify the times to be used regarding engine reliability estimates, (Reference K).

The reliability report for the ascent engine was received from BAC at the closing of this period and is presently being reviewed for approval of the contents.

4.1.2.2 Descent Engine

4.1.2.2.1 Rocketdyne Division, NAA

The major portion of the Rocketdyne reliability effort was devoted to preparation of supplementary reliability data to effect updating of the preliminary reliability report and its addended revision (References M and N). This updated report, expected to be submitted to GAEC in January 1964, takes cognizance of the GAEC revision request (Reference P and attachment). Also, a revised estimate of equipment reliability, resulting from a redefinition of the LEM Mission (Reference K), will be shown in this updated report.

4.1.2.2.2 Space Technology Laboratories

The Reliability Program Plan (Reference Q) and the Preliminary Reliability Report (Reference R) for the LEM descent engine are being revised per GAEC direction (References S, T, and U) and agreements made at the GAEC/STL reliability meeting of 3 and 4 October 1963. The revised documents are expected to be submitted to GAEC for approval in the near future.

The current STL estimate of engine reliability, (Reference V) as shown on Figure 5, is considered to be optimistic. Considering the source of failure rates used, a reasonable level of confidence regarding the

4.1.2.2.2 (continued)

validity of the estimate cannot be assumed. However, this estimate is being revised to delete consideration of the acceptance test firing time, and the reliability prediction model is being reformulated to account for each mission phase and corresponding K-factors per GAEC direction (Reference K).

Because there was no breakdown by phase of the reliability estimates by either Rocketdyne or STL, the mission success reliability estimates used in Section 3 of this report were brought forward from Reference B.

4.1.3 Failure Rate Investigation

Scrutiny of the supporting data for some failure rates used in GAEC calculations of propulsion subsystem reliability has made the acceptability of the estimates doubtful.

GAEC estimates of propulsion subsystem reliability will be revised following completion of a survey of the available failure data from the propulsion systems vendors and other applicable sources. From the survey results, the most realistic failure rate will be selected for each part type present in the subsystem design. The part application will be taken into account.

4.1.4 Helium Pressure Regulator Analysis

A comparative analysis (Reference A) was completed for two helium pressure regulators being considered for use in both the Reaction Control and the main Propulsion Subsystems of LEM. Analysis conclusions were based on the assumption that the reliability of a part is inherent in the function it performs and will be similar to other parts of similar functions.

Results of the analysis indicate that selection of the Sterer regulator design would provide the applicable subsystem with the higher inherent reliability.

4.1.5 Analysis Ground Rules

To insure consistent analysis methods for successive configurations of subsystem equipment, it is necessary to record the considerations accounted for in reliability estimates. Therefore, the following ground rules, pertaining to both the ascent and the descent propulsion subsystems, are established:

1. Propulsion subsystem reliability estimates shall consider the interaction of the separate ascent and descent propulsion subsystems.

   a. Ascent and descent propulsion subsystem reliability estimates combine in series for calculation of mission success probability.

   b. During the initial two-hundred (200) seconds of powered descent, the probability of a successful abort is derived from the parallel combination of the ascent and descent propulsion subsystem estimates.

      For the concluding two-hundred eighty (280) seconds of powered descent, the ascent propulsion subsystem alone contributes to the successful completion of an abort mission phase for crew safety.

2. The probability of explosion is considered during all LEM mission phases. Explosion probabilities attributed to the descent propulsion subsystem are neglected after lunar launch.

3. Mission success requires a minimum four (4) hour lunar stay. A twenty-three (23) hour lunar stay is considered in estimating the crew safety probability.

4. Environmental factors to be applied for reliability calculations of various mission phases are:

Engine Assemblies:	Boost Pressurized Non-boost Pressurized	1.0
	Boost Unpressurized Non-boost Unpressurized	.001

4.1.5 (continued)

All Other Propulsion Subsystem Equipment:

Boost Pressurized	10.0
Non-Boost Pressurized	1.0
Boost Unpressurized	.01
Non-Boost Unpressurized	.001

5. The regulator configurations and quad check valves of both main propulsion subsystems are considered to operate in quad redundancy for both mission success and crew safety. Redundant operation is provided for either the open or closed failure modes.

6. The normal mission for both the ascent and descent propulsion subsystems considers series operation of the helium storage tanks. An alternate mode of operation for the ascent propulsion subsystem assumes loss of one helium tank prior to lunar launch. The remaining helium tank will provide subsystem pressurization sufficient to permit the achievement of a clear pericynthion orbit, assuming CSM rescue.

7. The primary function of the ascent propulsion subsystem terminates at insertion into the transfer orbit. Crew safety considerations regarding explosion terminate when the LEM is abandoned after crew transfer is completed.

8. The ascent subsystem is initially pressurized for one-hundred (100) minutes on the lunar surface for checkout purposes.

9. The nominal mission does not include the parking orbit contingency after lunar launch.

4.1.6 Propellant Tankage Configuration Studies

Configuration studies were accomplished to determine comparative reliability estimates of dual tank, with (1) parallel feed and (2) series feed, and single tank propellant storage configurations for the ascent propulsion subsystem. Results indicate that the single tank configuration is the most reliable.

4.1.7 Discussion

4.1.7.1 Investigation of Failure Rates

The failure rates used in the current estimates of ascent and descent propulsion subsystem reliability, as published in the third Quarterly Reliability Status Report (Reference B), were obtained from an Aerojet General Corporation report (Reference D).

An investigation of these failure rates was undertaken to determine their validity for application to LEM propulsion subsystems.

As the investigation developed it was found that the Aerojet part failure rates had been operated upon by a variety of factors, not all of which have been made available to GAEC. This development makes the continued use of the affected rates untenable, since statistical justification for their use cannot be accomplished with any degree of confidence.

The reliability estimates for the initial weight-reliability configurations of the propulsion subsystems will be revised after acceptable failure rates have been determined. The failure rates shall be selected from a survey of failure data collected during use of similar equipments in operational and test program applications. Failure rate selections shall be made for each part type present in the subsystem design, and each shall possess sufficient background data to justify its use wherever possible.

4.1.7.2 Pre-launch Ready Condition

The reliability estimates shown on Table 4.1.2 include only that time during the mission from launch through lunar landing. The current reliability estimate by Rocketdyne for the descent engine for the pre-launch period (180 days from last engine firing) is .856329 which appears unreasonably low for this non-operating period. Effort will continue in the area of defining more accurately the time period involved, the major contributors to the low reliability and means of alleviating their effect, and the pre-launch checkout plans. Until such time as these items and their effects are known, it does not appear reasonable to include them in the over-all mission estimate.

4.1.7.3 Propellant Tankage Configuration Studies

During this report period there has been a concentrated design effort to revise the basic weight-reliability configuration of the ascent propulsion subsystem shown in Reference B, (the estimates of which are shown in Figure 5), to provide more efficient propellant utilization.

A shortcoming of the basic configuration is that helium "blow-by" can isolate the propellant remaining in one of the dual storage tanks, and effectively stop propellant flow to the engine. Helium "blow-by" is the condition that exists when helium passes through a tank, whose propellant supply has been exhausted, into either the fuel or oxidizer inlet line of the injector.

This condition results in complete loss of thrust and could seriously affect crew safety.

Three alternate tank configurations for ascent propellant storage have been proposed to decrease the quantity of propellant trapped in storage when helium "blow-by" occurs. Basic features of these proposed configurations are:

a. Interconnected dual tanks for each propellant with simultaneous parallel feed

b. Series connected dual tanks for each propellant

c. A single tank for each propellant

The dual tank, parallel feed configuration introduces check and solenoid valves to tank interconnect lines. These valves prevent intertank migration of propellant and insure that ullage unbalance will not exist prior to engine firing. The additional valves, however, increase the possibility of unequal flow rates from each tank, resulting in helium "blow-by" and trapped propellant.

The series connected dual tanks prevent intertank migration of propellant, prior to engine operation, by application of a zero gravity screen in the interconnecting propellant line. Helium "blow-by" directly to the engine inlet line is inhibited while a propellant supply is present by intra-tank baffles and the series connection of the dual tanks.

4.1.7.3 (continued)

The single tank configuration further reduces the residual propellant at engine burnout to that amount normally trapped by the tank internal baffle design.

Analyses of the three configurations were accomplished to determine comparative reliability estimates for use in the selection of a configuration that will best serve LEM requirements. These estimates (Table 4.1.1) were derived in Ref(W) by utilization of the same part failure rates, applicable operating times, and analysis methods used for estimates published in the second Quarterly Reliability Status Report (Reference C). The applied operating times of References B and C differ. Therefore, the results presented in Table 4.1.1 should not be compared with the ascent propellant tankage reliability estimate presented in Table 4.1.2.

Though the absolute results (Table 4.1.1) may be questioned because of the applied failure rates and operating times, valid conclusions can be made regarding the relative reliabilities of the respective configurations.

Results indicate that the single tank configuration is the most reliable.

TABLE 4.1.1

COMPARATIVE RELIABILITY ESTIMATES

PROPOSED PROPELLANT TANKAGE CONFIGURATIONS - ASCENT SUBSYSTEM	Mission Reliability
Dual Tank Storage:	
Parallel Feed	.99318
Series Feed	.99836
Single Tank Storage	.99861

TABLE 4.1.2

NOMINAL PROPULSION SUBSYSTEMS

Equipment	Reliability		Weight	
	Apportioned	Estimated	Apportioned	Estimated
Ascent Propulsion Susbystem	.999961	.984685	453.6	534.6
Engine	.999982	.998061		
Tankage LLO-270751A	.999979	.986599		
Helium Pressurization		.987535		
Propellant Tankage		.999052		
Descent Propulsion Subsystem	.999075	* .972207 ** .980019	1361.6	1564.8
Engine	.9991	* .9916 ** .999568		
Tankage LLO-279752B	.999975	.980443		
Helium Pressurization		.981873		
Propellant Tankage		.998544		

* Rocketdyne Engine ** STL Engine

4.1.8 References

A. Comparative Design Analysis, LMO-550-182, dated 13 December 1963, GAEC.

B. Quarterly Reliability Status Report, LPR-550-3, dated 1 November 1963, GAEC.

C. Quarterly Reliability Status Report, LPR-550-2, dated 1 August 1963, GAEC.

D. Reliability Study of Rocket Engine Types, No. 2140, dated November 1961, Aerojet General Corporation.

E. Design Control Specification - Ascent Engine, LSP-270-5A, dated 29 June 1963, GAEC.

F. Design Control Specification - Descent Engine, LSP-270-4A, dated 29 October 1963 (as amended), GAEC.

G. Design Control Specification - Variable Injector Descent Engine, LSP-270-6, dated 29 June 1963, as amended by LMO-276-35, dated 16 December 1963, GAEC.

H. Program Planning Report, No. 8258-910002, dated 16 September 1963, Bell Aerosystems Company.

J. Comments on Program Planning Report, LMO-275-14, dated 16 October 1963, GAEC.

K. Descent and Ascent Engine Specification Change, LMO-550-161, dated 5 November 1963, GAEC.

M. LEM Reliability Report, R-5226, dated 27 June 1963, Rocketdyne.

N. LEM Reliability Report, R-5226-1, dated 30 August 1963, Rocketdyne.

P. Request for Revision, LAV-274-13, dated 16 October 1963, GAEC.

Q. LEM Descent Engine, 7.0 Reliability Program Plan, STL Report 8438-6003-SW000, dated 3 August 1963.

R. LEM Descent Engine, Preliminary Reliability Report, STL Report 8437-6001-SC000, dated 3 September 1963.

4.1.8 (continued)

S. GAEC Memorandum, LMO-276-11, dated 10 Septemer 1963

T. GAEC Memorandum, LMO-550-136, dated 27 September 1963

U. GAEC Memorandum, LMO-559-146, dated 10 October 1963

V. Monthly Reliability Report, Paragraph 7.1.4.9, No. 8438-6014-SC000, dated 10 August 1963, STL.

W. GAEC Memorandum, LED-550-18, dated November 1963.

4.2 GROUND SUPPORT EQUIPMENT

4.2.1 Summary and Conclusions

The GSE Reliability effort this past quarter has been concentrated in the following areas:

a) review of GSE apportionment techniques.

b) preliminary review of LEM checkout measurements list

c) revision of FEA form for use in GSE failure prediction.

An effort was undertaken to come up with a realistic apportionment for the GSE, primarily in the mission-essential category. This renewed effort is necessary because the provisional estimate of .999991 (as used in LPR-550-1) no longer has real significance. The initial apportionment was purely an index of mission success probability and is not sufficient for GSE usage. One possible approach to a reapportionment will be to relate the pre-launch checkout measurements to a probability that no undetected defects remain in LEM after checkout. Other factors that may warrant consideration for this analysis include: test equipment and/or measurement accuracy, false-alarm probability, test equipment-induced spacecraft failures, repetitive checkouts, and others as mentioned in Reference (a). Regardless of the technique(s) used, a reliability/weight trade-off of sensors will be a governing factor.

An advance copy of the LEM checkout measurements list was received during this report period listing proposed measurements for all LEM subsystems. Roughly, 65 per cent of the 965 measurements are collected via the Flight PCM and interleaved with the remaining 35 per cent which are obtained by the PACE carry-on equipment. It is hoped that this list can be categorized into those measurements needed for crew safety, malfunction isolation, and pre-flight evaluation and subsequently optimized to provide the most reliable set of test points consistent with the weight, accessibility, and space constraints. The functional level of malfunction isolation must also be defined along with the test points required.

4.2.1 (continued)

There have been no major carry-on equipment configuration changes; the functional block diagram (Figure 4.12.1) of Reference (g) remains essentially intact. The PACE-S/C reliability block diagram has been partially updated to place the uplink on the same level of assembly as the downlink, i.e., the equipment level. This updated diagram is shown as Figure 4.2.1 of this report. Table 4.2.1 gives the latest reliability figures (apportioned and estimated) and weight (estimated) for the LCE-PUL.

The anticipated effort for the ensuing quarter shall include the following tasks:

a. establish new apportionment ground rules for GSE
b. continue analysis of LEM checkout measurements list

4.2.2 General Function Description

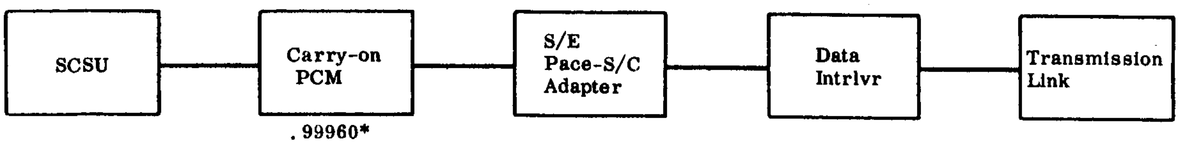
4.2.2.1 PACE-S/C

Although the PACE-S/C carry-on has remained virtually fixed in configuration since the last report, it might be well to mention in retrospect other information received in the last quarter.

Information has been received on preliminary weight and placement estimates of both carry-on equipment and its associated test points (see References b, c, e, and f). Once again, it must be emphasized that, although the carry-on equipment in itself does not fly, certain portions of the test point/cabling complex do, and must be considered accordingly.

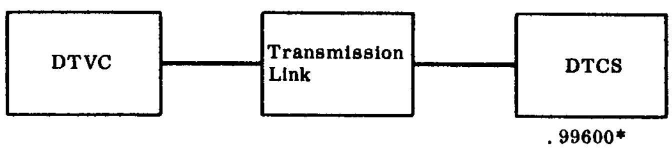
4.2.2.2 Bench Maintenance Equipment (BME)

Nothing to report this quarter.



Pace Downlink (LCE-PDL)

*See Note 2, Table 4.2.2



Pace Uplink (LCE-PUL)

Figure 4.2.1
Reliability Block Diagram (Eqpt. Level) Pace-S/C Carry-on

4.2.2.3 Fluids Support Equipment

Nothing to report this quarter.

4.2.3 References

a. LMO-410-42, "GSE Math Model for LEM Checkout Equipment"

b. LMO-410-76, "LEM Design Constraints Imposed by Pre-Flight System Checkout Requirements"

c. LMO-410-81, "PACE-S/C Uplink and Downlink"

d. LMO-410-102, "LEM Measurements List

e. LMO-410-107, "Placement of PACE S/C Carry-On Equipment During LEM Checkout"

f. NAA PACE-S/C Interface and Design Information

g. LPR-550-3, third Quarterly Reliability Status Report

TABLE 4.2.1

SUBSYSTEM ANALYSIS SUMMARY

<table>
<tr><th>Equipment</th><th colspan="4">Reliability</th><th colspan="2" rowspan="2">Weight</th></tr>
<tr><th rowspan="2">GSE</th><th colspan="2">Apportioned</th><th colspan="2">Estimated</th></tr>
<tr><th>Mission Success</th><th>Crew Safety</th><th>Mission Success</th><th>Crew Safety</th><th>Apportioned</th><th>Estimate (3)</th></tr>
<tr><td>LCE-PDL</td><td rowspan="2">.999991 (1)</td><td>N/A</td><td>.99960 (2)</td><td>N/A</td><td>N/A</td><td>240#</td></tr>
<tr><td>LCE-PUL</td><td>N/A</td><td>.99600 (2)</td><td>N/A</td><td>N/A</td><td>125#</td></tr>
</table>

NOTES:

(1) Currently under review, see paragraph 4.2.1

(2) Based on NAA/SID procurement specifications and (4) hour c/o sequence

(3) Non-flyable equiment weight only, does not include test points, connectors, and cabling which could add to fly-away weight

4.3 REACTION CONTROL SUBSYSTEM

4.3.1 Summary and Conclusions

The Reaction Control Subsystem configuration has not changed from that described in the past two Quarterly Progress Reports. Efforts during this quarter were directed along the lines of studying details of the previous analyses, i.e., methods of analysis, failure mode and effects analysis, reliability implications of interfaces with other subsystems and alternate configurations used in the weight reliability studies.

4.3.2 Major Efforts Anticipated in Next Quarter

In the next quarter, a compilation of failure rates on Propulsion and Reaction Control Systems will continue. At the present time, failure rates are not sufficient to provide a high degree of statistical and/or engineering confidence in absolute values.

A thruster path study will be undertaken to further define engine reliability. Up to now, it has been assued that eight out of sixteen thrusters are needed to complete the mission (considered an approximation). For the purposes of the thruster path study it will be assumed that the present RCS configuration will be used. Below is an outline of the study:

1. A detailed analysis of the modes of operation of the RCS
2. A phase by phase breakdown of the mission
3. Determination of requirements for each phase
4. Generation of a reliability model for the respective phases.

4.3.3 Discussion

4.3.3.1 Weight-Reliability Study

These studies were initiated during the last reporting period and will be discussed here. The objective of these studies is to aid in the definition of a LEM vehicle which represents a reasonable balance between system reliability and effective weight.

Five RCS configurations were evaluated ranging from the simplest that would perform attitude control to the current configuration (LDW-310-10100). The reliability block diagrams for each configuration are shown in Figures 4.3.1 through 4.3.5, along with specific characteristics of each configuration. Table 4.3.1 includes independent mission success and crew safety reliabilities. The details of this study can be found in reference (e).

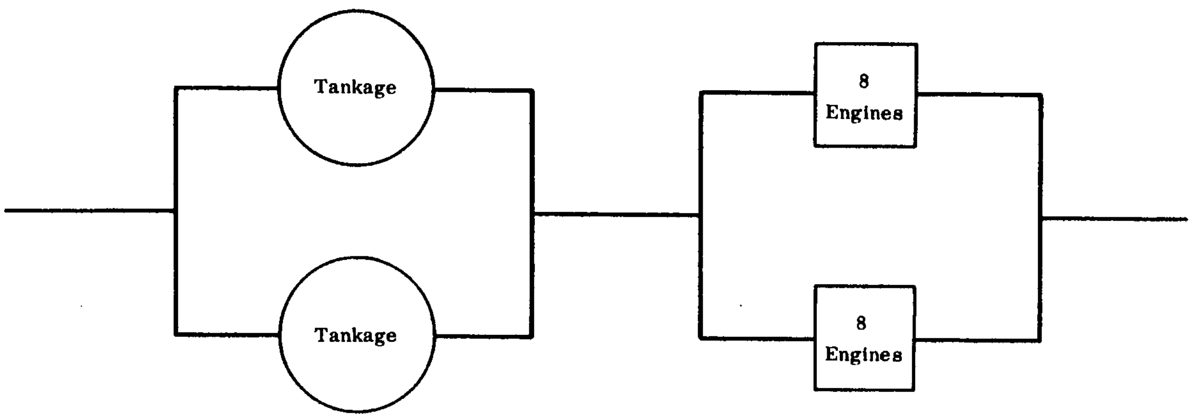
TABLE 4.3.1

Weight-Reliability Configuration Table

Figure No.	Weight	R(M) Mission Success Reliability	R(S) Crew Safety Reliability
4.3.1	546.6	0.9974	0.9999+
4.3.2	528.8	0.9973	0.9999+
4.3.3	488.5	0.9966	0.9992
4.3.4	534.7	0.9974	0.9999
4.3.5	476.8	0.99078	0.9979

NOTE:

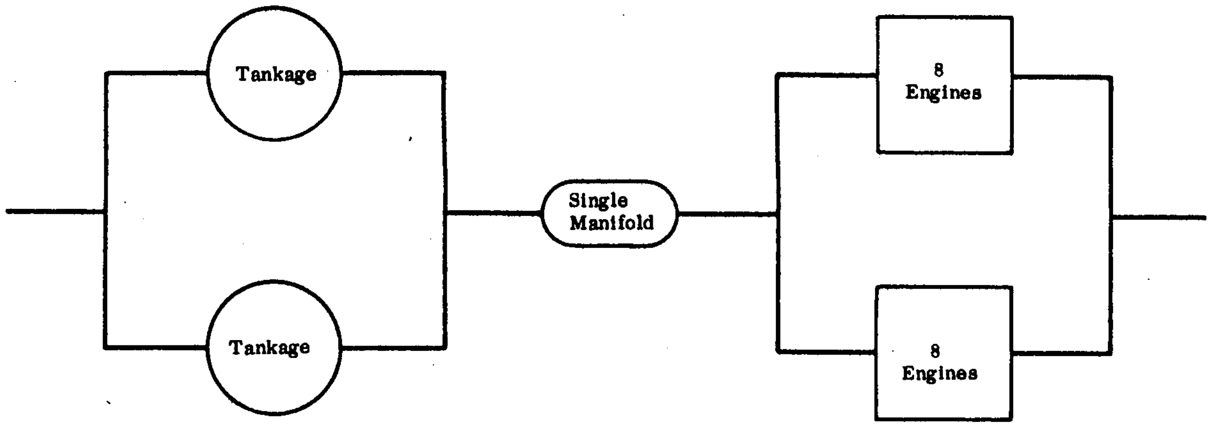
1. R(M) calculation does not include lunar stay time from 4-to-23 hours.
2. For R(M) calculations from pre-separation to hover, both legs of tankage and engine systems are considered in series.
3. For R(S) calculations from pre-separation to hover, legs are considered in parallel redundance.
4. For powered descent from hover to touchdown, R(M) calculation considers only 1 out of 2 legs required.



Configuration Characteristics:

Tankage is parallel except for pre-separation through powered descent to 1000 feet; engines are in parallel throughout the mission.

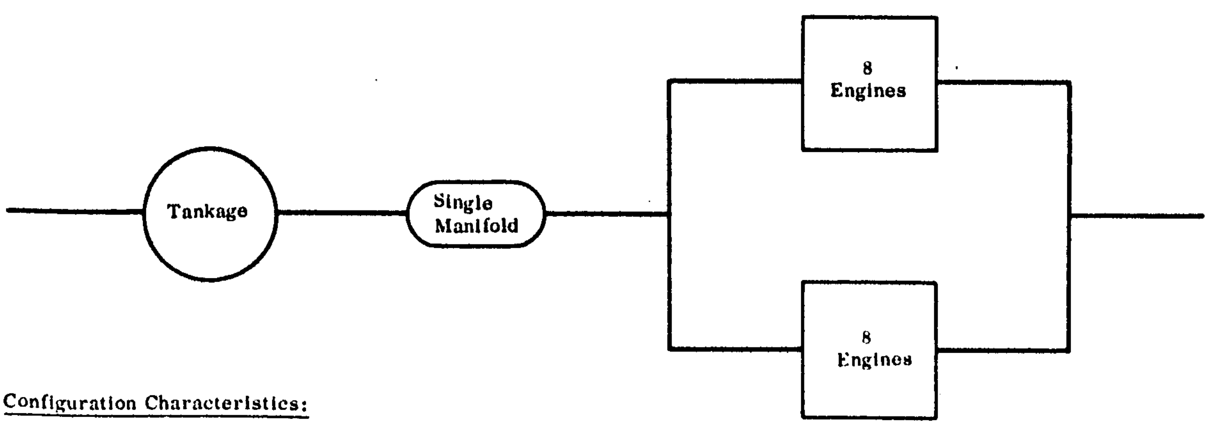
Figure 4.3.1



Configuration Characteristics:

1. Engines and tankage are same as Figure 4.3.1.
2. Addition of single manifold which acts as a series link in the reliability model. Current configuration contains dual manifold, hence single failure will not jeopardize mission.

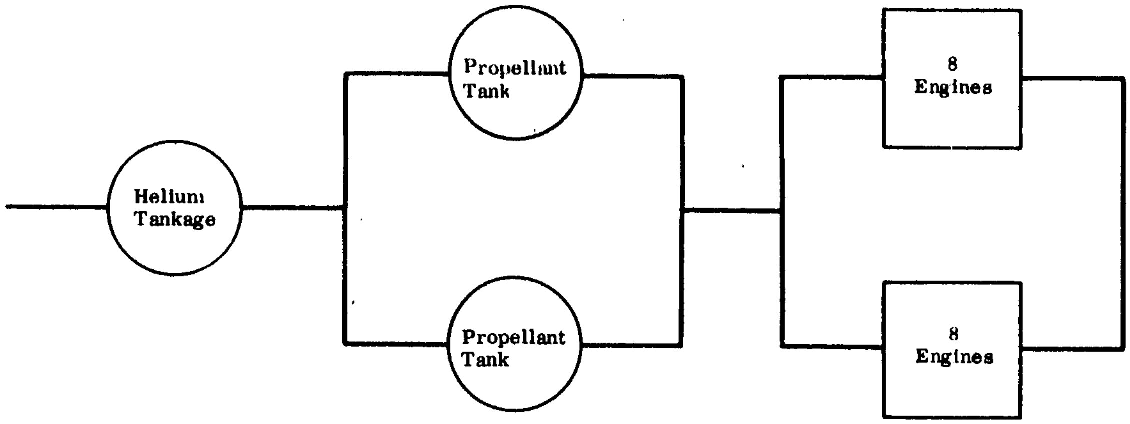
Figure 4.3.2



Configuration Characteristics:

1. Engines same as current configuration, Figure 4.3.1.
2. Helium tankage and controls, propellant tankage and single manifolds are series links in the reliability model.

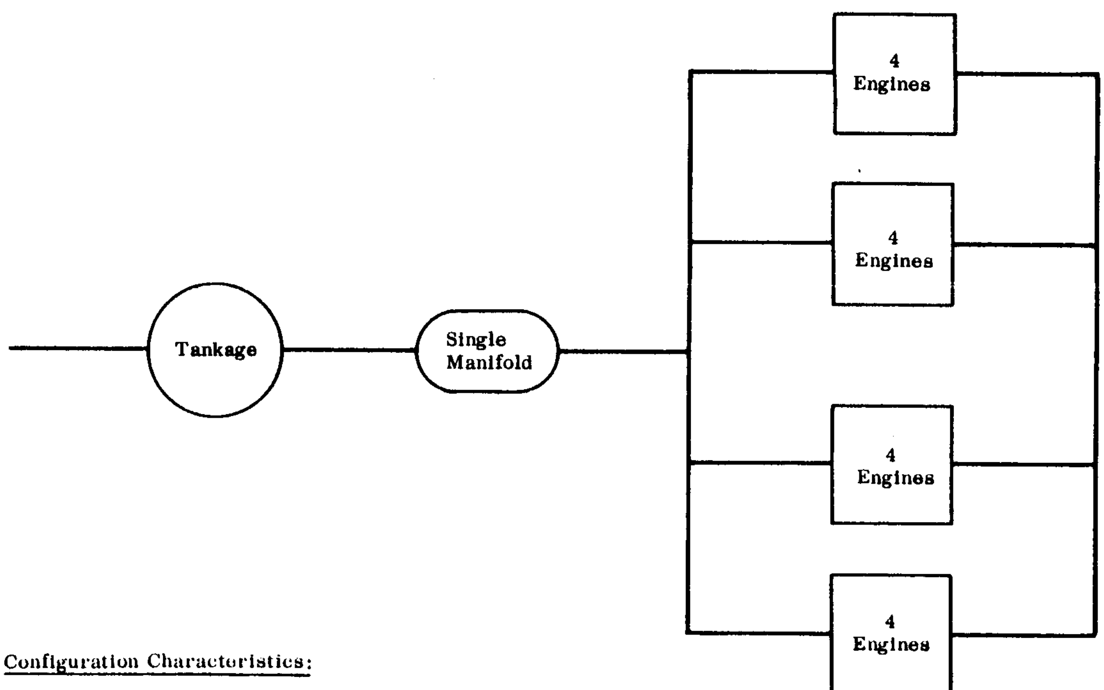
Figure 4.3.3



Configuration Characteristics:

1. Single element of Helium supply and controls, dual propellant tanks and redundant pair thrusters with dual manifolds.
2. Helium tankage and controls are series links in the reliability model.

Figure 4.3.4



Configuration Characteristics:

1. Helium tankage and controls, propellant tankage and single manifold are series links in the reliability model.
2. Engines are quads as opposed to pairs in other cases. (LPR-550-2, dated, August 1963)
3. Three out of four quads must operate for success.

Figure 4.3.5

4.3.3.2 Failure Mode and Effects Analysis

This analysis was completed for the current RCS configuration (LDW-310-10100), Reference A. Reference B. gives a breakdown of the RCS. It is planned to update this study periodically as the subsystem becomes operational. It was recommended that in the Helium Pressurization Subsystem the addition of four (4) check valves in series downstream of the two-stage regulators is necessary if a significant portion of the failure rate is associated with external leakage. As the configuration currently stands, there is a possibility of the pressure regulator system allowing helium to flow from the redundant regulator through the helium manifold back into the ruptured regulator and out of the system. I also recommended considering addition of high pressure relief valves in the Helium Pressurization Subsystem for crew and personnel safety.

4.3.3.3 Regulator Comparative Analysis

A comparative analysis of helium pressure regulators, proposed by the Fairchild-Stratos Corporation and Sterer Engineering, for use in the LEM RCS, has been completed. The analysis was accomplished at the request of the LEM RCS Subsystem group to aid in the selection of a regulator. Results of the analysis (see Reference C) indicate that the Sterer Regulator would best serve the reliability requirements. The reliability of the parts comprising the Sterer Regulator Assembly are similar to parts of like functions and proven reliabilities in the Fairchild Regulator Assembly. The reliability of a part is inherent to the function it performs. In all, fifteen (15) parameters were analyzed, and nine (9) of the most significant favor the Sterer design. Features which give the Sterer Regulator Assembly a higher inherent reliability are single valve and valve seat of each stage, an integral valve body, reduced number of parts moving independently, and total number of part functions susceptible to leakage.

4.3.3.4 Isolation Valve Study

A study was completed (see Reference D) comparing RCS mission success reliabilities with and without cluster isolation valves. It was pointed out that the elimination of cluster isolation valves could necessitate shutting down one set of propellant tanks (half the RCS propellant supply) in the event of a single engine failure. Thus, an open, closed, or

4.3.3.4 Isolation Valve Study (continued)

leakage malfunction of anyone of 32 engine valves could abort the LEM mission. Moreover, failure of a cluster could require shutdown of both sets of tanks; and, therefore, catastrophic loss of vehicle control. Experience to date with the Marquardt engines suggests that engine (or cluster) fragmentation is, and could continue to be, a principal mode of failure. Malfunction of any of several combinations of two (2) engines in the system could have the same result. The effect on RCS reliability would be severe. The elimination of the valves would reduce reliability of the engines from .999931 to .987050 for mission success, and would reduce the current RCS mission success reliability from .997797 to .984916. Since the apportioned mission success reliability is .999804, the impact on reliability would be severe if the cluster isolation valves are eliminated.

4.3.3.5 Ascent Interconnect Study

As the RCS presently stands, the Ascent Interconnect is a degraded mode of operation. The possibility of utilizing ascent propellant during the powered ascent phase makes the interconnect a series link in the reliability model. This makes for a more complex system with no apparent gain in reliability. This is characterized by the crossfeed valves, which are now squibs, by changing them to solenoids for opening and closing purposes. A comparison showed that in the nominal mode (current) the mission success reliability is .9999984, while in the nominal mode utilizing the ascent interconnect the mission success reliability is .9999971. Based on the results, it has been decided to stay with the existing mission philosophy.

A by-product of this study was to consider whether the ascent interconnect is really needed. It presently accounts for approximately 25 pounds (four valves, two filters, lines, and trapped propellant) and is expected to be a costly development item. A study will be performed as to its affects on mission success and crew safety and reported in the next quarterly.

4.3.3.6 Feasibility of Completing Mission in Event on RCS Tankage System Fails

This study was conducted in order to investigate other possible modes of operation of the RCS to enhance system reliability. The question has arisen as to whether an abort is required during descent if one of the two RCS Propellant Tankage Subsystems fails . The question centeres about the ground rule requiring abort if the next failure would jeopardize crew safety. One position taken is that RCS tanks with positive expulsion devices (bladders) are neceaary for crew survival. Opposed to this position is that the reaction control engines can be operated from contingency propellants in the ascent tankage (not equipped with positive expulsion devices so that propellant is available only under lunar gravity or +x axis thrust) being used to perform standard aborts with the Command Module performing the rendezvous.

The design of the RCS Tankage Subsystem is such that a leakage type failure depleting propellants is the most likely. The types of failures that would make a tankage subsystem useless instantaneously will probably be lethal. The valving in the RCS tankage is such that most serious leak type failures can be controlled. The next result is that even if both RCS tankage subsystem fail some RCS tankage capability will be available to stabilize the LEM during critical periods such as docking or crew transfer if the available Δ V is employed judiciously.

The conclusion is reached that an abort is not required in an event of an RCS tankage subsystem failure if adequate contingency propellants are provided in the ascent tankage subsystem. In the course of the study it was discovered that a center-of-gravity (CG) control problem exists when one RCS tankage subsystem fails. Operational procedures and propellant allocations can minimize this danger.

Recommendations are as follows:

1. A change in logic of the S and C should be incorporated to minimize the fuel penalty during powered flight.
2. Abort not be required in event of failure of one of RCS tankage subsystems.
3. Develop feasibility of implementing a "cross coupling" mode for attitude control during powered flight and operational procedures which will cope with the CG unbalance problem (which can result from an RCS tankage subsystem failure).

4.3.4 Ground Rules

There are special reliability features in the RCS which require ground rules fundamental to the system. In order to clarify the results of numerous analyses and better coordinate with other subsystems, a basic ground rule list was prepared. This list is expected to get larger as the program progresses and the mission is better defined. Below is the listing:

1. The mission is aborted if either RCS tankage subsystem fails during descent.

2. Abort if next failure would jeopardize crew safety.

3. Full redundancy is available for X translation and X, Y, and Z rotation - Y and Z translations are not redundant.

4. A failure of either valves or engine will result in an engine pair being shut off by the thrust chamber isolation valves. This implies that the four oxidizer and propellant solenoid valves (two of each) are considered in series.

5. Criterion for mission success: from translunar flight to hover all tankage is in series; thrusters are redundant throughout the mission.

6. Four stress levels are considered to be applied to the mission time: boost pressurized, -10.0; boost unpressurized, -1.0; non-boost pressurized, -.01; non-boost unpressurized, -0.001.

7. Translation by means of thrusting on Y or Z axis with one thruster and removing the torque by another pair of thrusters (with propellant penalty) is a degraded mode of operation.

8. Failure data is based on ground environment with the system pressurized.

4.3.5 Vendor Monitoring

4.3.5.1 Marquardt Corporation

The scope of TMC effort agreed on in Phase "B" subcontract negotiations was reviewed. As a result several scope changes were embodied in the Phase "C" final negotiations. TMC will analyze, isolate and attempt to prevent malfunctions and failures in order to achieve the required reliability goals on the RCS propellant system and thrust chamber assembly.

The Marquardt Program, received by Reliability on 21 October 1963, has been reviewed and the Reliability section found generally unacceptable. The text contains very little specific data.

A complete monitoring of TMC effort is underway and will be reported in the next Quarterly. TMC status appears in Table 4.3.2.

4.3.5.2 Bell Aerosystems Company

The reliability effort associated with propellant tankage will be performed by Bell. The "common usage" tanks will be procured directly by Grumman and furnished to TMC for system integration. The program plan is due February 1964. Table 4.3.3 shows subcontractor status. Technical progress will be described in the next Quarterly Report.

4.3.6 References

A. LED-550-14, "RCS Failure Mode and Effects Analysis", dated 8 November 1963.

B. LMO-310-73, "Reaction Control Subsystem Description and Update", dated 24 October 1963.

C. LMO-550-182, "Reliability Comparative Design Analysis for RCS", dated 13 December 1963.

D. LMO-310-87, "RCS Cluster Isolation Valves and Failure Detection Logic", dated 6 December 1963.

TABLE 4.3.2
SUBCONTRACTOR STATUS

Subcontractor: MARQUARDT CORPORATION
Specification No: LSP-310-2B (REVISED)
Vendor Reqmt. Doc. No: LVR-310-2
Purchase Order No: 2-18831

Equipment: REACTION CONTROL TCA
Date: 18 September 1963
Date: 7 May 1963
Date: 22 July 1963

MILESTONES	Jan. 1963	2	3	4	5	6	7	8	9	10	11	12	Jan. 1964	2	3	4	5	6	7	8	9	10	11	12	Jan. 1965
Specification Preparation					◧				▲	□															
Vendor Reqmt. Doc. Prep.					◧		□																		
Proposal Review			△							□															
Vendor Negotiation			△							□															
Vendor Go-Ahead							□																		
Program Plan										■															
Reliability Report												▲													
Failure Effect Analysis																									
Failure Mode Prediction Analysis																									
Configuration Analysis																									
Component Part Approval																									
Circuit Analysis																									
Maintainability Analysis																									
Reliability Assurance Plan																									
Reliability Assurance Analysis																									
Apportionment and Estimate																									
Design Review																									

△ Due

▲ Received

□ Accept

◧ Unacceptable Minor Revisions

■ Rejected - Major Revision

◭ Reissued

TABLE 4.3.3
SUBCONTRACTOR STATUS

Subcontractor: BELL AEROSYSTEMS COMPANY
Specification No: LSP-310-405
Vendor Reqmt. Doc. No: LVR-310-405
Purchase Order No:

Equipment: REACTION CONTROL TANK.
Date: 29 August 1963
Date: 20 September 1963
Date:

MILESTONES	Jan. 1963	2	3	4	5	6	7	8	9	10	11	12	Jan. 1964	2	3	4	5	6	7	8	9	10	11	12	Jan. 1965
Specification Preparation										□															
Vendor Reqmt. Doc. Prep.										□															
Proposal Review											△														
Vendor Negotiation											△														
Vendor Go-Ahead												△													
Program Plan																									
Reliability Report																									
Failure Effect Analysis																									
Failure Mode Prediction Analysis																									
Configuration Analysis																									
Component Part Approval																									
Circuit Analysis																									
Maintainability Analysis																									
Reliability Assurance Plan																									
Reliability Assurance Analysis																									
Apportionment and Estimate																									
Design Review																									

△ Due
▲ Received
□ Accept
◧ Unacceptable Minor Revisions
■ Rejected - Major Revision
◭ Reissued

4.4 STABILIZATION AND CONTROL SUBSYSTEM

During this period the reliability effort was directed toward the following areas:

1. Weight-Reliability Study

2. Study of Gimbal Angle Sequence Transformation Assembly (GASTA) and Attitude Indicator

3. Revision of Parts Count and Reliability Estimate for GCA and ATCA.

4. Vendor Negotiations and Review Specifications.

Reliability data is summarized in Table 4.4.2; tasks performed to date are summarized in Table 4.4.3.

A summary of the ground rules that were used in analyzing the S and C Subsystem are shown below:

1. The mission of the SCS includes the operating and non-operating phases from launch to rendezvous and docking as shown in the mission profile.

2. No contingency phase is included in the reliability studies.

3. Operating time on the lunar surface is the same for a minimum 4-hour stay as for the full 24-hour stay.

4. The RGA, AC, and TC have dual redundancy throughout the mission.

5. A full synchronous orbit is assumed for calculations in this report.

4.4.1 Discussion

4.4.1.1 The work performed in this quarter consisted partly of the application of LED-550-11, which gives the lower-bound reliability of the Control Electronics Function of the SCS. This report develops the reliability mathematical model for the Control Electronics Function. A memorandum (LMO-550-183) comparing the reliability between a one-wire and two-wire configuration for main engine on/off switching was also published during this quarter, in conjunction with the Navigation and Guidance Reliability group. This analysis estimated the reliability of a single wire for engine on/off switching as 0.998154 while the estimated reliability of a two-wire configuration was 0.9999966.

4.4.1.2 Reference (a) shows a parts count and failure rate determination for the Gimbal Angle Sequence Transformation Assembly (GASTA) and the Attitude Indicator (8-Ball). Two configurations of the GASTA and 8-Ball are analyzed in Reference (a) and their associated reliabilities shown. A parts count and reliability estimate for the Guidance Coupler Assembly (GCA) and the Attitude and Translation Control Assembly (ATCA) are described in Reference (a). Back-up Guidance Control Panel and ARA Power Supply equivalent operating time are delineated in Table 4.4.1. Tables 4.4.2 and 4.4.3 give a summary of the reliabilities and weights and work performed in the Stabilization and Control System for 1963 respectively.

4.4.1.3 In the weight-reliability study of the Stabilization and Control Subsystem performed during the third quarter, four different configurations of the Control Electronics Section (CES) were evaluated for crew safety and mission success reliability. The Back-up Guidance was not considered in this analysis, because it is so closely tied to the guidance function. For this reason, the Back-up Guidance considerations were included with those of the Navigation and Guidance Subsystem.

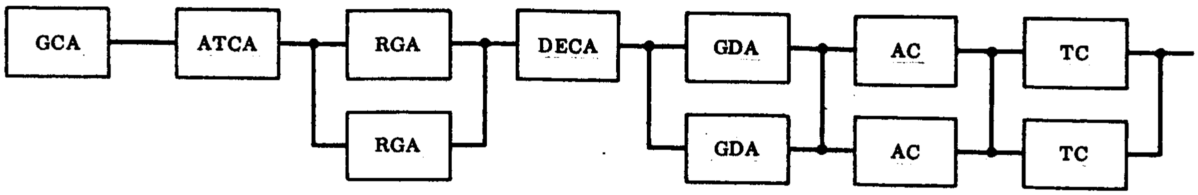
The first or nominal configuration of the CES consisted of non-redundant Guidance Coupler Assembly (GCA), Attitude and Translation Control Assembly (ATCA), and Descent Engine Control Assembly (DECA). The Rate Gyro Assembly RGA), Attitude Controller (AC), Translation Controller (TC), and Gimbal Drive Assembly (GDA) are all considered redundant.

The second configuration is similar to the first configuration except for the fact that the GDA is considered non-redundant, to reflect GAEC thinking at that time. Since then, the GDA non-redundant and removed the failure and combinational logic from the ATCA. This was performed to reduce the weight of the Stabilization and Control Subsystem to a minimum.

The fourth configuration represents a high reliability method for implementing the Control Electronics Section of the SCS. Except for the DECA, all assemblies have been considered redundant. The back-up ATCA used in this configuration is the degraded model with the failure and combination logic removed. Relays have been included to provide the switching from the primary mode to the back-up mode.

Figure 4.4.1 shows the general reliability block diagram for each of the above configurations along with the mission success and crew safety reliabilities and weight estimates. The model used for calculating the mission success and crew safety reliabilities is outlined in Reference (g).

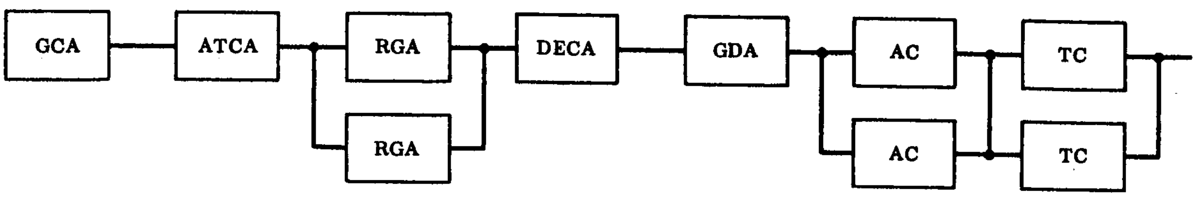
I. Nominal Configuration



6 lbs | 15 lbs | 4.4 lbs | 4.5 lbs | 6 lbs | 9.6 lbs | 9 lbs

Total Weight: 54.5 lbs.
Reliability: Mission Success: 0.995830
Crew Safety: 0.996638

II. Nominal Configuration with Non-Redundant GDA



6 lbs | 15 lbs | 4.4 lbs | 4.5 lbs | 3 lbs | 9.6 lbs | 9 lbs

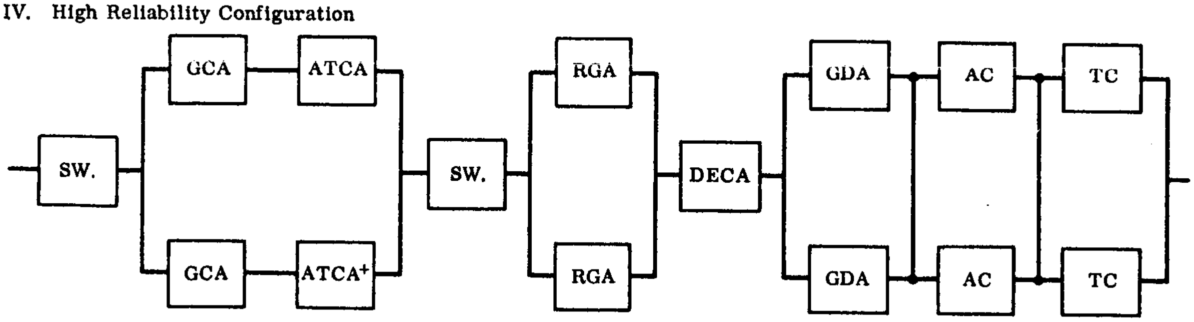
Total Weight: 51.5 lbs
Reliability: Mission Success: 0.995750
Crew Safety: 0.996628

III. Light Weight Configuration

6 lbs | 12 lbs | 2.2 lbs | 4.5 lbs | 3 lbs | 4.8 lbs | 4.5 lbs

Total Weight: 37.0 lbs
Reliability: Mission Success: 0.983830
Crew Safety: 0.987288

IV. High Reliability Configuration



12 lbs | 27 lbs | 4.4 lbs | 4.5 lbs | 6 lbs | 9.6 lbs | 9 lbs

Total Weight: 72.5 lbs
Reliability: Mission Success: .999882
Crew Safety: .999925

* The weights recorded are those valid as of 15 December, 1963, and may differ from those recorded in System Analysis Section

\+ Degraded ATCA; failure and combinational logic removed

FIGURE 4.4.1

S & C Weight-Reliability Study *

4.4.1.4 Due to the difference in coordinate system of the Attitude Indicator relative to the guidance platform, it is necessary to have a Gimbal Angle Sequence Transformation Assembly (GASTA). A parts count shows the failure rate (NL) of the GASTA to be 46.435×10^{-6} and of the indicator to be 59.377×10^{-6}. The reliability of a single indicator configuration is 0.9987; that of a two-indicator configuration is 0.9995. In a two-indicator configuration, an indicator would be available to each of the LEM crew members. Both configurations are well below the apportioned reliability (0.999985). The details of the above study can be found in Reference (a).

4.4.1.5 The parts count for the GCA is the first one made which is based on design concept. Although the design concept is preliminary, the reliability estimate indicates that the apportioned reliability is feasible.

The parts count for the ATCA has been shown before, but not in complete form, and without showing the breakdown into sub-assemblies. There has also been some revision in the parts count itself. For these details and those of the GCA, see Reference (b). The reliability estimates of the above assemblies are summarized in Table 4.4.2.

TABLE 4.4.1

EQUIPMENT EQUIVALENT OPERATING TIME ESTIMATES*

ARA POWER SUPPLY AND BACK-UP GUIDANCE CONTROL PANEL

Mission Phase	Total Time (min.)	Operate Non-Boost Time x1.0 (min.)	Operate Boost Time x10.0 (min.)	Non-Operate Non-Boost Time x0.001 (min.)	Non-Operate Boost Time x0.01 (min.)	Equivalent Operating Time (hr.)
Pre-separation (D-J)	5091.0	115.75	0	4.87	1.04	2.03
Separation (K1, K2)	10.0	8.7	13.0	0	0	0.36
Injection (K3)	0.5	0	5.0	0	0	0.083
Synchronous Orbit (K4, K5)	151.9	151.9	0	0	0	2.53
Powered Descent (K6, K7)	6.0	0	60	0	0	1.0
Hover To Touchdown (K8)	2.0	0	20	0	0	0.33
Pre-launch Lunar (L1-L6)	1378.5	150	0	1.23	0	2.52
Ascent (M1)	6.0	0	60	0	0	1.0
Midcourse Without Contingency (M3, M4)	58.1	58	1	0	0	0.983
Rendezvous (M5)	24.0	24	0	0	0	0.4
Docking (M6)	15.0	15	0	0	0	0.25
					Total Time (w/o cont.)	= 11.5 hrs.

* Times obtained from LDW-390-10000B, LEM Electrical Load Analysis, dated 5 November 1963.

TABLE 4.4.2

LEM STABILIZATION AND CONTROL SYSTEM RELIABILITY DATA SUMMARY

EQUIPMENT	FAILURE RATE Σ NLx10^{-6}/hr.	EQUIVALENT TIME (hours)	Q (NLT)	ESTIMATED RELIABILITY (1-Q)=R(M)	APPORTIONED RELIABILITY MISSION SUCCESS	APPORTIONED RELIABILITY CREW SAFETY	WEIGHT ESTIMATED
I CES					.9986005	.9996856	
1. RGA	79.2	11.32	.0008965	.9991035	.99000	.999900	4.4
2. DECA-GDA	72.966				.9999956	.9997613	7.5
a. DECA	15.766	3.06	.0000482	.9999518	.999987		
b. GDA (2)	57.2	3.32	.0001899	.9998100	.999913		6.0
3. ATCA-PS	157.1*	11.07	.0017391	.9982609	.999000	.999900	15.0
a. ATCA	98.1*	11.07	.0010860	.998914			
b. Power Supply	59.5	11.07	.0006587	.9993413			
4. GCA	17.6**	11.07	.0001948	.9998052	.999900	.999900	6.0
5. AC	99.462	11.07	.0011010	.998899	.992929	.99995	4.8
6. TC	97.616	11.07	.0010806	.9989194	.992929	.99995	4.5
							Total 42.2
II BGS					.998500	.9967	
1. Programmer	351.442	11.07	.0038905	.9961095	.999400	.998712	20.0
2. ARA	1131.647	10.77	.0121878	.9878122	.999100	.997988	40.0
a. Electronics-PS	106.829						
1. Electronics	97.139	10.77	.0010462	.9989538			
2. Power Supply	9.69	11.50	.0001114	.9998886			
b. Platform	760.869	10.77	.0081945	.9918055			
c. Accelerometer	158.121	10.77	.00170296		.99829704		
3. Control Panel	2.475	11.50	.00002846	..99997154			
							Total 60.0

TABLE 4.4.2

LEM STABILIZATION AND CONTROL SYSTEM RELIABILITY DATA SUMMARY

(continued)

EQUIPMENT	FAILURE RATE $NL \times 10^{-6}$/hr.	EQUIVALENT TIME (hours)	Q (NLT)	ESTIMATED RELIABILITY (1-Q)=R(M)	APPORTIONED RELIABILITY		WEIGHT ESTIMATED
					MISSION SUCCESS	CREW SAFETY	
III DISPLAYS	105.82	11.50	.001217	.998783	.999985		
1. GASTA	46.44	11.50	.000534	.999466	.9999925		8.0
2. Indicators (2)	59.38	11.50	.000683	.999317	.9999925		6.0
							TOTAL 14.0

* Equivalent Failure Rate, calculated from reliability number, using method of derivation in LPR-550-2, with updated parts count.

** Preliminary: Calculated from incomplete design data.

Note:

1. $R=e^{-NLT}$: When the exponent NLT is sufficiently small, the difference between e^{-NLT} and (1-NLT) is negligible and is disregarded for the purposes of this table.
2. Two RGA's will be used in parallel. The estimated reliability becomes .9999991933; apportioned, .999900.
3. Two AC's will be used in parallel. The estimated reliability becomes .9999988; apportioned, .999950.
4. Two TC's will be used in parallel. The estimated reliability becomes .9999988; apportioned, .999950.

TABLE 4.4.3

RELIABILITY TASK SUMMARY

	Unit	Parts Count	Failure Rate	Configuration Analysis	Mode Analysis	Reliability Block Diagram	Phase-Mission Analysis	Failure Effect Analysis	Total Equivalent Time	Weight	R(M)	
											Apportioned	Estimated
I	CES				1	1	3,5	1*	3,6	3,6	3	3
	1. RGA	5	2,5	2*						3,6	3	3
	2. DECA-GDA	2	2	2		1				3	3	3
	a. DECA	2	2	2		4						3
	b. GDA (2)		2	2								3
	3. ATCA-PS'	2	2							3	3	3
	a. ATCA	5,6	5,6	2		2						
	b. Power Supply	6	6									
	4. GCA	5*6	6							3	3	3
	5. AC	5	5							3	3	3
	6. TC	5	5							3	3	3
II	BGS	1*3	1	1				1*	3,6	3	3	3
	1. Programmer	1*3	3							3	3	3
	2. ARA	1*3	3							3	3	3
	a. Electro.-PS	1*3	3									
	1. Electro.	1*3	3									
	2. Pwr.Supply		6									
	b. Platform	1*3	3									
	c. Accelerometer	1*3	3									
	3. Control Panel	3	3									
III	DISPLAYS	6	6								6	6
	1. GASTA	6	6								6	6
	2. Indicators (2)	6	6	6							6	6

* Preliminary:
1 LPR-550-1, dated 3-30-63
2 LPR-550-2, dated [illegible]-63
3 LPR-550-3, dated 11-1-63
4 LMO-550-144, dated 9-10-63
5 LED-550-11, dated 10-23-63
6 LPR-550-4, dated 2-1-64

4.4.1.6 The following proposals were reviewed in this period:

HONEYWELL AERONAUTICAL DIVISION

Proposal 3B-S-95, Rate Gyro Assembly for the LEM Stabilization and Control Subsystem, dated 20 November 1963

KEARFOTT DIVISION

Proposal E-1028412G, Rate Gyro Assembly for the Lunar Excursion Module (LEM), dated 20 November 1963

NORTHROP NORTRONICS

Proposal E-867, AC/AC Rate Gyro Assembly for Lunar Excursion Module, dated 20 November 1963.

Vendor negotiations were conducted with the successful bidder (Kearfott Division, General Precision, Incorporated) on the Reliability Program for the Rate Gyro Assembly.

4.4.1.7 Reliability Effort for Next Period

In the next period attention will be directed toward the back-up guidance system, expecially in the areas which have not been covered to date as indicated by Table(7), such as configuration analysis, reliability block diagram, etc.. An updated parts count and failure rate determination will be performed on the GCA and new revised operating times on all assemblies will be determined. Calculation of the reliability of the automatic mode of operation for the Control Electronics Section will be continued in the next period.

4.4.2 References

A. LMO-550-202, "Attitude Indicator Configuration Analysis", dated 3 December 1963.

B. LMO-550-203, "Updating of Reliability Estimates of GCA and ATCA of SCS", dated 10 December 1963.

4.5 NAVIGATION AND GUIDANCE SUBSYSTEM

4.5.1 Efforts during this report period have been expended in the following areas:

- Continued the updating of the reliability estimate of the N & G subsystem as more empirical data on failure rates were received and/or when modifications to the mission plan occurred.
- Continued participation in weight-reliability study as it applies to the overall Navigation and Guidance function.
- Completion of the configuration analyses of the onboard S-Band communication equipment as a possible backup for the rendezvous radar.
- Review of the RCA Program Plan, dated 20 December 1963.
- The initiation of configuration analyses of the computer-radar interface units in order to determine the relative reliability effects due to the installation of individual interface units in each discrete radar instead of the common interface unit, which is presently in the rendezvous radar.
- Configuration analysis on both a functional and reliability basis of the possible modification of the engine ON/OFF control signal interface between the PNGS and SCS subsystems.
- Evaluation of landing radar subcontractor proposals from Ryan Aeronautical Co., LFE, GPL, and Raytheon.

4.5.2 As of the writing of this report, coordination meetings with MIT, MSC and GAEC have been held to determine the applicable MTBF of the PNGS which significantly affects the overall guidance function reliability. This failure rate estimate will be implemented in the reliability model in conjunction with the radars and backup guidance system to determine the R(M) and R(S) of the LEM guidance function. Continued liaison with MIT during the next report period should alleviate the reliability discrepancies and methodology differences used to assess the reliabilities of the respective MIT PNGS units. GAEC has recently received reference (d), from MIT, which is expected to clarify some of the heretofore problem areas. The document contains the reliability progress for the period ending October 31, 1963.

4.5.3 Based on information contained in paragraph 4.5.5, those estimates of the overall guidance function R(M) and R(S) used in the weight-reliability studies will be updated in accordance with reestimates of PNGS.

4.5.4 The configuration analyses of the onboard S-Band communication equipment, as a possible replacement for the X-Band rendezvous radar, were completed during this period. Two different S-Band configurations were evaluated as compared to the present radar configuration. These included; (a) replacing the LEM X-Band radar with an S-Band unified communication system using the present S-Band transponder with additional ranging equipment, (b) replacing the CSM X-Band radar with the existing S-Band transponder and additional ranging equipment and without the LEM X-Band transponder electronics.

The calculations showed that the reliabilities for both S-Band configurations as compared to the present system changed rather insignificantly and subsequently caused negligible change to the overall guidance function reliability. Based on these conclusions and other determining factors, such as weight and capability, the systems coordination group stated that the most feasible scheme for weight reduction would be the replacement of the X-Band backup rendezvous radar on the CSM with the S-Band system.

4.5.5 The RCA radar reliability plan of the RCA Program Plan was reviewed during this period. The reliability plan generally complies with the GAEC reliability requirements and philosophy as indicated in the applicable performance specification and vendor request. Its underlying philosophy, is to indoctrinate the design engineer and all associated managerial personnel in those procedures which will result in the most reliable design possible. Some of those areas requiring further clarification include the following:

- Failure rate sources and justification.
- The weight-reliability tradeoff methodology.
- Aspects of the RCA circuit analyses, specifically for worst-case utilization and testing.

These few areas which do require clarification are expected to be resolved in the near future. It is also expected that several changes to the plan will be made as new requirements in the design and functionability are considered. The major emphasis in reviewing the program plan was to ascertain the intent and purpose of the reliability effort.

4.5.5.1 Since the last quarterly report there has been no significant change in the estimated parts count of either the rendezvous

4.5.5.1 (continued)

radar-transponder or the landing radar. The basic failure rates, which were agreed upon in the early negotiations with RCA and which are used to determine the overall unit failure rates have not changed. Because of these conditions the failure rate estimates for the radar units are thos indicated in reference (a) Table 4.5.8 through 4.5.10.

4.5.5.2 A reliability analysis, of a configuration using separate radar-computer interface units as opposed to the present configuration using a common computer interface unit, which could possibly affect the basic guidance function reliability model, was initiated. The mathematical model for the guidance function reliability, which is shown in reference (b), was used for comparing the two configurations. The preliminary estimates based on the aforementioned condition, indicates that the incremental change in R(M) is insignificant between the possible modes of operation.

The change in crew safety has not yet been determined. The computations are in process and should be available in the near future.

4.5.5.3 During this period a probability study pertaining to engine on/off controls was completed. This study was initiated in order to help resolve the question of using two (2) on/off interface signal wires between MIT and GAEC equipment or a single wire signal. The probability of a signal failure causing an erroneous ascent or descent engine command, using a two wire configuration or a single wire configuration was investigated using the LGC and engine sequencer of the SCS. The study showed that the use of the two wire system has a higher probability of keeping the engine firing than does the use of a one wire system. The calculations, recommendations and qualifications are shown in reference (c).

References

(a) LPR-550-3, "Quarterly Reliability Status Report", 1 November 1963.

(b) LED-290-3, "LEM Guidance Redundancy Study", 15 July 1963.

(c) LMO-550-183 "Ascent/Descent Engine ON-OFF Control Failure Probability Calculations", 18 December 1963.

(d) R-429 "Reliability and Quality Assurance Progress Report", December 1963

4.6 COMMUNICATIONS SUBSYSTEM

4.6.1 System Components General Status

This period has seen extensive vendor technical negotiations with the Radio Corporation of America (RCA). Thus, it has been the time for proposal analysis (reference a) and hardware considerations.

RCA in reference(a)points out that attainment of the reliability goals presented in reference (b) would be extremely difficult, particularly if the system is a serial model. Full solution of the problem will require the application of screened high reliability parts, astute design and redundancies.

It was recommended that any further redundancy considerations be held in abeyance until the "in progress" weight reliability studies affecting over-all system design philosophy are completed. Following the decisions of this over-all study similar joint GAEC-RCA studies will be made inside the communication subsystem. Such studies may serve as a guide in formulating approaches to attain the specified reliability and in the selective restatement of some reliability goals.

So, at this time, the hardware in the system components received renewed attention for potential reliability improvement. As presently conceived, both the LEM parts reliability group and the intended vendor propose the use of high reliability parts (wherever available) which have undergone a 100% supplemental preconditioning cycle and concomitant testing and screening. Empirical knowledge of high reliability parts show the present state of the art but these field results are showing lower failure rates than MIL parts. Hence, reliability predictions for system components using high reliability parts will exhibit a reliability growth as field failure rates are gathered and corrective actions are incorporated to attain target rates. Superimposed on this reliability growth will be the reliability gains of screening. A table comparing the failure rate (L) of the critical major communication system components using standard MIL parts and the present parts philosophy is presented below.

TABLE 4.6.1

SYSTEM COMPONENT PREDICTED

RELIABILITY GROWTH TABLE

S-Band Section	L (1) Using MIL-Hdbk. 217 Parts	L (2) Using High Rel. Screened Parts
Transponder	206.77	108.45
Power Amplifier	110.70	42.07
Steerable Antenna	174.14	33.96
VHF Transceiver	119.58	12.70
Premodulation Processor	25.20	15.36
Audio Center Single Station	41.85	8.19

(1) See reference (c)
(2) See reference (b)

This table shows projected improvements in the ranges of 2 to 1 through 10 to 1. It was introduced at this time because technical negotiations established that reference (a) used this type of parts philosophy and control during its preparation. Present indications are that high reliability part programs are appreciably depressing MIL-Hdbk.217 failure rates. (See references (d) and (e)). Thus, table 4.6.1 may be admitted as a projected reliability growth for system components. It must be borne in mind that final verification is yet to come in the form of further field feedback. However, the present thinking has it that failure rates should continue to be depressed as both incipient failures are removed and corrective actions are incorporated. As much as possible, empiricism should be the final criterion by which

4.6.1 (Cont.)

we accept column 2 or further predicted reliability growth. At any rate, it must be remembered that any improved failure rate assigned to a part during a final predication is for the actual flight hardware.

4.6.1.1 S-Band Section Status

Note in table 4.6.1 that the S-Band section has the largest failure rates. This follows as a function of the S-Band's complexity, usage of exotic parts and its multi-functioned role. Although large reliability gains can be made in this function with parts selections and control and design simplicity, much additional reliability growth could be accomplished by designing into its many signal paths fail-safe features and manual over-ride switches.. These switches would control functional redundancy in order to accomplish the highest timely mode or to time share modes during the various mission phases in the event of prime signal path failure.

4.6.1.1.1 Power Amplifier (Amplitron Status)

In this period a trip was made to the Raytheon Company to determine amplitron progress. (See reference (f)). Very limited life runs have been made on prototype tubes. However, both the time and number of tubes constitute an insufficient sample to make any statistical determinations of failure rate or longevity or to learn something about failure modes. Raytheon admits the necessity for some life testing and, in fact, has prepared an excellent technical proposal (see reference (g)) delineating a comprehensive reliability program. Implementation of such a program is necessary to establish some confidence in this tube.

Since considerable development support for the amplitron comes from Jet Propulsion Laboratory (JPL) close liaison has been maintained with them. Through a recent telecon consultation between R. Brunson of the GAEC LEM communications group and P. Goodwin of JPL, it was learned that one tube of a batch of five amplitrons will be delivered to JPL for design verification testing in mid January of 1964. Thus, the present consensus of opinion is that the amplitron is not yet flight hardware.

4.6.1.1.2 S-Band Antenna Status

(a) Steerable Antenna. During technical negotiations it was established that the proposed RCA multi-element design for the steerable antenna would have less reliability than a dish unless it were overdesigned. This would of course contribute to the weight problem. It was decided to take a second closer look at this problem for both technical and reliability improvement.

(b) Erectable Antenna. On December 10, 1963, the Dalmo Victor Company made a presentation to GAEC demonstrating a half scale model of an erectable antenna. This model featured a simple screw jack mechanism which erects an umbrella-like structure (dish). Easy manual assistance in the event of sticky operation during spring unfolding of any ribs is possible. However, their engineers believe that careful material research and test will dispose of any sticky operation during the mission. Furthermore, such a mechanical construction utilizes human factor qualities not possessed by inflatable gear. Repetitive learning is easily invoked on the same unit of this particular mechanical system since it may be repacked and erected over and over again. In comparison, an inflatable system is essentially one shot due to repacking problems and moreover, is subject to punctures during both training and the actual mission. To date, the simple positive mechanical system shown by this model has the best hardware approach for the erectable antenna provided material problems are obviated.

4.6.2 Communications Equipment Packaging Considerations

Throughout this time a general electronic packaging specification (see reference (h)) has been in joint preparation by GAEC and its consultant, Francis Associates (FA). Although, this document can control most aspects of electronic packaging there are some problem areas of the communication gear which deserve special consideration. Of deep concern are problems associated with noise, high voltage (HV) characteristics and the peculiarities of radio frequency (RF). These special packaging cases are presently being worked out through the joint engineering efforts of GAEC, RCA and FA. When firm decisions are made,they will appear in the communication design control specification (reference (b)) as deviations to reference (h). Because even slight packaging failures can induce conditions causing related failures in communication performance (e.g. noise) or in the actual electronic parts, the LEM reliability activity is avidly following and contributing to all special communication packaging exercises. Apropos of this discussion, the most urgent of the special items are presented below.

4.6.2.1 Sealing Considerations

Reference (h) permits the use of drain holes (weep holes) and so exposes equipment interiors to both launch site and space environments. Serious reasons exist which render such an approach inadvisable for some portions of the communication gear. Both high voltages (circa 2KV) and 20 watts of RF Power will be generated in this equipment. Thus, sections of this gear require hermetic sealing and pressurization at a fraction of an atmosphere. Past high altitude and space programs have experienced considerable difficulty with corona, arcing, flash-over and established high voltage tracks. Both degraded performance (e.g. noise and power loss) and catastrophic part failure can ensue. Also, the multipactor phenomenon occurs at much lower RF frequencies and powers than are generated here. Furthermore, the time for resolution of these special problems has caused schedule delays. In practice, realizable hardware has been sealed and pressurized. (See References (i) and (j).) Presently, the question doesn't seem to be whether to seal and pressurize, but rather to what extent. Most of the moot points seem to center about weight. Nevertheless, local pressurized compartments can defeat the minimization of thermal interfaces thereby creating thermal embarrassment of heat sensitive parts. Increased heat sinking and boxes within boxes could result in a weight stalemate.

The remaining solution being entertained is to avoid internal box readily maintainable interfaces, conformally coat with a hard encapsulant all connections and avoid hermetic sealing. Besides introducing difficult maintenance and test problems, this could create electrical coupling and tuning problems. However, if total coating saves appreciable weight and works electrically, it is an attractive route. Of course, this would not answer the multipactor problem. Here, pressurization has been proven empirically to be the best answer. (See Reference (i)).

Finally, the GAEC reliability section is reminding Communication equipment designers and consultants that the communication gear must pass a certain sequence of environmental tests as per MIL-STD-810 and other stringent reliability tests which can not be relaxed to accommodate inefficient packaging.

4.6.2.2 Connector Considerations

Reliability problems similar to the above occur in connectors. They are also being considered for sealing. Should any entire electronic replaceable assembly (ERA) be sealed, then it might be advisable to box mount connectors. Also under scrutiny are pin separation and separate power, signal and RF coaxial connectors.

4.6.2.3 Electronic Replaceable Assembly (ERA) Quantity

Whether to employ one or two communication ERA's has been carefully explored. Present thinking favors two ERA's over one multifunction ERA housing all communications. The following concepts give the most influential points in favor of using two ERA's:

(1) The generation of two RF powers inside one case can cause interference due to case conduction and resonating compartments. The extra shielding and parts required to circumvent such interaction could nullify the light weight advantage.

(2) Packing all communication electronics in one case allows no room for growth if configurations must be changed for reliability or performance.

(3) On the launch pad, failure of a single function in a multifunction ERA requires the removal of all functions from the vehicles. This would require more elaborate requalification of the systems.

(4) A greater number of spare ERA's would be required to support a single multifunction unit because sparing would be influenced by the function with the lowest MTBF and function density.

4.6.2.4 Wiring Considerations

An examination of the interconnecting techniques suggested in reference (h) showed that a cabling harness sub-assembly would have a weight advantage over a welded matrix wiring assembly. Medium density wiring need not be supported in a case size matrix, this saves encapsulant. This approach also appears to have the edge in reliability since a welded wiring matrix has a new joint for each wire direction change.

4.6.2.4 (continued)

The small wiring harness approach also has another important advantage for communication equipment, namely, versatility and flexibility in wire dress. This capability can be used to eliminate interaction and coupling. Experiments and changes are not readily accomplished with hard matrices.

4.6.2.5 Testing Considerations

Coordination between the reliability group and the specification engineers established that ERA's undergoing electrical test or bench operation shoudl be attached to a cold plate with flowing coolant. This would simulate actual mission conditions and safeguard against the thermal overstress of other underdesigned methods.

4.6.2.6 Running Time Meter for Amplitron

In order to log all time accruing on the amplitron for the purpose of determining replacement, such an instrument is necessary. Elapsed time indicators for failure reporting are recommended in the packaging specification and are under study.

4.6.2.7 Elastomeric Buffer Coatings

Since hard encapsulants strain and fracture electronic parts when setting or during thermal cycling, it was decided to pre-coat parts in an elastomeric coating before hard encapsulation. Further impetus was given to the predipping process to alleviate part parameter variations due to dimensional changes. This is of particular interest in the frequency sensitive circuits of communications gear.

4.6.2.8 Packaging Testing

It is being strongly suggested that all packaging approaches be demonstrated in actual test as soon as possible. This should occur before actual LEM hardware is enclosed by such techniques to avoid technical problems and schedule delays.

4.6.3 Weight-Reliability Summary

A weight-reliability summary table, Table 4.6.2, is appended to this report. The table has been brought forward from reference (k). It was kept in this form since both mission times and mission success philosophies are moot points in the communications subsystem. When current mission analyses are completed and firm success philosophies are generated, changes may occur in this table.

4.6.4 Reference List

a. "Technical Plan for LEM Communications Subsystem", Prop. No. 347130, DSG No. 63-588-83B, Radio Corporation of America, dated 7 October 1963

b. Design Control Specification for Communications Subsystem, LSP-380-1, GAEC, dated 8 August 1963

c. Quarterly Reliability Status Report, LPR-550-2, GAEC, dated 1 August 1963

d. Letter from R. L. Shannon to C. G. Moore, 63 AN/NS8636, Autonetics, 27 November 1963

e. Reliability Stress and Failure Rate Data for Electronic Equipment, MIL-HDBK-217, dated 8 August 1962

f. Arleth, J., Report of Trip to Raytheon Company on 17 and 18 October 1963 to Ascertain Amplitron Status, LMO-550-165, dated 16 November 1963, GAEC

g. High Reliability Program for Space Communications Amplitrons, Technical Proposal PMP-1399, dated August 1963, Raytheon Company

h. "General Specification for Electronic Packaging", LSP-360-002, dated 18 November 1963, GAEC

i. Baller, H. and Phillips, E., Investigations of Failures of Wideband OAO Transmitter in Vacuum Test, TM-756, dated 16 July 1963, Hughes Aircraft Company

j. Dummer, G. and Griffin, N., Electronic Equipment Reliability, 1960, Wiley and Sons, Incorporated

k. Quarterly Reliability Status Report, LPR-550-3, dated 1 November 1963, GAEC

TABLE 4.6.2

WEIGHT-RELIABILITY SUMMARY TABLE

Equipment	Apportioned Reliability	Estimated Reliability*	Apportioned Weight	Estimated Weight
S-Band Section	0.999980	0.986153	35.29	56 - Ascent 46 - Descent
VHF Section	0.999960	0.993603	14.05	22.3
Audio Center	0.999980	0.996652	3.15	5
Premodulation Processor	0.999990	0.998992	6.30	10

* based on 40-hour operation

4.7 ENVIRONMENTAL CONTROL SUBSYSTEM

4.7.1 Reliability Objectives

The reliability objectives assigned during this period were the completion of the following tasks:

1. Weight-Reliability Study on a minimum of five (5) E.C.S. configurations (paragraph 4.7.2)

2. Establish, survey, and monitor the subcontractor's reliability program (paragraph 4.7.3)

3. Interface with North American Aviation, Hamilton Standard, and MSC on interface problems concerning reliability with the Portable Life Support System (PLSS) (paragraph 4.7.4).

4.7.2 Weight-Reliability Study

4.7.2.1 Summary

A detailed summay of the reliability analysis for configurations studied in the quarter is presented in Table 4.7.1.

4.7.2.2 Conclusion, Weight-Reliability Study

The studies indicate that there are many possible paths to improve reliability and reduce weight. From this study it was concluded that the greatest weight reduction is achieved by staging water. Reliability was improved significantly by providing a separate heat transport loop for cooling of critical electronic equipment.

The weight reduction and reliability improvements were not achieved in a significant magnitude to conclude the effort in the weight-reliability study. Hence, additional effort will be directed toward achieving more significant improvements.

4.7.2.3 Procedure For Weight-Reliability Studies

4.7.2.3.1 Selection of Configurations

The initial planning for the selection of configurations imposed a mandatory requirement that all configurations selected must meet the requirements of mission plan, LPL-540-1, and

4.7.2.3.1 (continued)

its amendment, LMO-540-19. The alternate configurations selected meet the basic objectives of the mission plan from both a functional and mission viewpoint.

The basic approach was first to select a base configuration from which trade-off studies could be accomplished. The trade-off studies are made by defining alternate configurations which purposely represent configurations that are more and less reliable than the base configuration and weight more and less than the base configuration. In the process of the analysis, other configurations materialize some of which strike a better balance between weight and reliability.

Those selected represent a judicious elimination of weight and improvement in reliability. Configurations selected were reviewed and approved by a weight-reliability panel of engineers selected from the weight, reliability, system and subsystem groups.

4.7.2.4 Description of Configurations

Configurations 1 through 6 are briefly described below. The reliability block diagrams and other details of this study are contained in LED -550-20, "Weight-Reliability Configuration Study of ECS", 12 December 1963. The results of this study are summarized in Table 4.7.1.

Configuration 1:

Configuration (1) is illustrated in engineering schematic drawing LDW-330-10000, Revision "A". The configuration was studied in a previous Reliability Quarterly Report. However, changes in ground rules and a more exacting mathematical technique was used resulting in a slight difference in the reliability numbers.

Configuration 2:

In order to achieve a better balance and effect a trade-off against the base configuration, relative to what effect the lack of redundancy has in the system, redundant items were eliminated. Since a weight reduction seemed feasible with staging consumables (water, oxygen), it was decided to stage water which could result in the lightest configuration.

4.7.2.4 (continued)

Configuration 3:

Configuration (3) delineates the state of the art of the E.C.S. during this period. The features of this configuration are: a sapce radiator, staged water, elimination of multiple redundancy for LIOH Canisters, and removal of redundant water separator. Additional weight savings was accomplished by the removal of one (1) of three (3) Glycol Pumps and its associated hardware in the heat transport section.

Configuration 4:

Configuration (4) represents a moderately redundant configuration by providing an additionalLIOH Canister Assembly, three separate space radiators, and staged water.

Configuration 5:

Configuration (5) is an illustration of what is considered to be the most reliable configuration to study. Water is unstaged, three space radiators are used, another redundant LIOH Canister Assembly is provided, and a suit-circuit fan was added. Redundancy was also provided by adding on another cabin fan assembly. Another significant item was the providing of a complete and separate heat transport loop for cooling of critical electronic equipment.

Configuration 6:

Configuration (6) is the same as the base configuration but it represents the LEM-ECS System, if it can be considered passive for the pre-separation stage of the mission. Considerable changes would be represented in this system and the work is not concluded in this area since there is a feasibility study associated with the EPS. This is a study and is presented as an indication of what can be accomplished in this area.

4.7.2.5 The following are the ground rules used in analyzing the ECS:

1. PLSS backs up the ECS and GOX in the EPS. A PLSS reliability for LEM crew safety of .999995 for a 12-hour mission was assumed.

2. LEM is checked out and is in operating condition prior to being manned by the crew.

4.7.2.5 (continued)

3. A minimum of four (4) hours lunar stay is assumed for the calculation of mission success reliability, and a twenty-three (23) hour lunar stay is assumed for the calculation of crew safety reliability.

4. Outside lunar exploration is accomplished and samples are collected.

5. Oxygen systems and heat transport sections are operating from ground launch through docking.

6. No manual overrides are considered for unmanned phases of mission.

7. Equivalent operating time is the same as first and second Quarterly Report less the 17.7 hours of the contingent orbit.

8. The ECS System contains consumable sufficient for the nominal mission.

9. No in-flight maintenance is considered.

10. Only the instrumentation shown by the schematic drawing was considered in this study.

4.7.2.6 Analysis Procedure

A detailed study of the techniques used are documented in the weight-reliability study memorandum LED-550-20 for ECS. An explanation of the mission times is required for a full understanding of this report.

The summary sheet has four (4) distinct equivalent operating times for various missions. They are:

a. The nominal mission of 48 hours, which includes a full lunar stay of approximately 23 hours and an ascent contingency orbit phase of approximately 18 hours.

b. A 30 hour mission, consistency of four-hour lunar stay and an eighteen-hour contingency orbit phase.

c. A thirteen hour mission consistency of four-hours lunar stay and does not include a contingency orbit phase.

d. A method as described in 25 October 1963 LEM Engineering Memorandum by S. A. Weisberg/G. H. Sandler/C. G. Moore, Subject: Method For Calculating Subsystem Mission Success And Crew Safety Probabilities For Weight-Reliability Studies.

4.7.2.6.1 Failure Rates

These failure rates selected are the same ones utilized in previous reliability quarterly reports.

4.7.3 Subcontractor Reliability Program

During the time of this reporting interval, the subcontractor has formulated the reliability approach and detailed the objectives in the program plan and initial reliability reports. Certain exceptions were taken by GAEC after reviewing these documents and the comments are presented in ensuing paragraphs.

4.7.3.1 Hamilton Standard Program Plan

Endorsement of the program plan was withheld by GAEC Reliability on those sections directly affecting Reliability.

The evaluation of the program plan submitted to GAEC is documented in LEM Engineering Memorandum LMO-550-176, dated 4 December 1963.

The referenced memorandum brought forth the salient points of non-compliance. Coordination is now being affected which shall eliminate GAEC Reliability objections. The specific objections are related to the general inability of H.S.D. to explicitly define their program plan and to give credence to all GAEC requirements.

4.7.3.2 Hamilton Standard Reliability Reports

The H.S.D. initial reliability assessment of the ECS was produced in H.S.D. report SV H SER 2807. GAEC reliability was critical of the information contained in parts of this report since insufficient evidence was supplied to support the conclusions reached.

In order to eliminate this problem and achieve an impetus toward resolving other outstanding problems, GAEC convened a reliability coordination meeting on 4 December 1963 at GAEC. The minutes of this meeting are documented in LMO-550-170.

4.7.3.2 (continued)

The outstanding problem in the H.S.D. effort was the inability to provide supporting documentation to reliability conclusions. One salient item covered at this meeting was the H.S.D. substantiation of the use of brushless-dc motors for application in powering the cabin fans and glycol pumps.

These motors do not meet the current state of the art and the inability of H.S.D. to provide a schematic drawing of their brushless-dc motor is of prime concern to GAEC Reliability.

Repeated requests for a schematic of the chosen motor has resulted in the statement that a final decision has not been reached on which type of brushless-dc motor is to be utilized. At the present time there are many concepts being studied for switching and commutation and it is paramount that a reliability evaluation of this type of motor be completed prior to final selection. The reliability objection to the use of a d-c brushless motor is presented in LMO-550-164, dated 14 November 1963.

GAEC Reliability is currently preparing a test plan for d-c brushless motors in order to establish the necessary test background. Reliability shall also accomplish a parts count reliability prediction when detailed design information becomes available.

4.7.3.3 H.S.D. Layout Drawing Review

GAEC Reliability is also reviewing H.S.D. layout drawings and integrating the reliability effort with the design personnel at GAEC.

H.S.D. layout drawings reviewed in this time period were:

H.S.D. Layout No.	Title
SVL-10126	Separator-Water LEM
L-10115	Accumulator Slycol
SVL-10128	LIOH Selector Valve and Water Separator Valve

4.7.3.3 (continued)

The water separator and glycol accumulator were designed out of fiberglass material. Reliability has objected to the use of fiberglass until it can be proven conclusively that fiberglass does not outgass, and is proven erosion resistant for these applications.

Analyses of the Hamilton Standard Layout, SVL-10128, for the LIOH Selector Valve (item 114) and Water Separator Selector Valve indicates that the design approach was unsound. The report indicates that no human factor considerations were exercised, normal aircraft engineering standards were not used, i.e., blind-tapped holes, and that no loads or moment could be transferred into the valve bodies, although misalignment features were not provided in mounting ducting. These comments were transmitted to our design group and they are taking action with the vender in this area.

4.7.4 Portable Life Support System

The PLSS is an integral part of the LEM mission and its reliability must be defined to predict a reliability for the LEM mission.

In order to determine what reliability was used by NAA, MSC and HSD, GAEC reliability attended the C/M Space Suit Interface Coordination Meeting No. 6, held at NAA, Downey, California, on 16 and 17 October 1963. Agenda item No. 4 covered Space Suit Reliability Requirements.

It was determined at this interface meeting that no numerical reliability was assigned at that time. NAA had accomplished a reliability study but did not predict a numerical reliability. GAEC Reliability requested from MSC personnel that a numerical reliability value be established. This was taken under consideration by MSC.

Since this coordination meeting, GAEC has prepared an interface specification in which GAEC Reliability considerations as included. This specification, Grumman Specification No. LSP-340-6, "Space Suit Assembly, Performance and Interface", is not currently being released. It is anticipated that acceptance of this interface specification will overcome the objections of GAEC Reliability with the Space Suit Assembly.

TABLE 4.7.1

SUMMARY OF WEIGHT-RELIABILITY STUDIES FOR ECS

Config. No.	Equiv. LEM Mission Time	R(M)	R(M) Considering Abort Probability	R(S)	R(S) Considering Abort Probability	Weight (lbs.)	
						Dry	Wet
1	48 30 13	.980069 .982192 .985213	.9823906 .986187	.994252 .997767 .998335	.996775	234	606
2	48 30 13	.963100 .966654 .972487	.9667629 .973977 n	.989824 .999961 .997001	.999518	221	593
3	48 30 13	.976143 .978312 .981825	.9785517 .982659	.994398 .997356 .998088	.999693	235	547
4	48 30 13	.975566 .977799 .981323	.9780105 .982174	.993155 .997216 .998013	.999681	248	560
5	48 30 13	.979021 .980974 .983792	.9811273 .984415	.994198 .997580 .998327	.999731	264	606
6	48 30 13	.991511 .993658 .996715				234	606
H.S.D. Estimate	48	.9889					

4.8 ELECTRICAL POWER SUBSYSTEM (EPS)

During this report period the major reliability effort has been directed toward weight-reliability optimization of the EPS. In pursuit of this goal, crew safety and mission success probabilities were calculated for six power generation configuration and five power inversion and conversion configurations.

In addition, reliability results of the inverter study were obtained where the supply of electrical power other than 28 VDC was considered. This effort differs from the weight-reliability study where all loads other than 28 VDC were taken into consideration plus the environmental control system motors. Documents submitted by subcontractors and reviewed by Grumman Reliability Control are listed at the end of this section.

4.8.1 Power Generating Subsystem (PGS)

The Power Generating Subsystem consists of fuel cells, fuel cell reactant tankage, and emergency battery. From the 19 configurations analyzed in LED-550-12 consisting of 1, 2 and 3 fuel cells plus 1, 2 and 3 hydrogen tanks plus 2 and 3 oxygen tanks both staged and unstaged, six configurations were chosen for the PGS input to the weight-reliability program. The mission success reliabilities were computed on a phase by phase and conditional basis. The only ground rule change from LED-550-12 is that: 4 hour lunar-stay shall not be curtailed by a loss of capability to sustain orbital contingency. The results are summarized in Table 4.8.1.

A conceptional design review was held at Pratt & Whitney Aircraft on December 8 and 9, 1963. The reliability presentation consisted of an analysis section and an implementation program by which P & WA intends to arrive at the apportioned reliability of 0.990 for a single fuel cell stack.

The analysis portion consisted of a listing of failure rates and a justification of how they were chosen. The actual analysis pointed out that all parts are in series for reliability considerations and a failure of any single item would result in failure of the entire fuel cell stack.

As part of the program, to implement the attainment of a high reliability, a failure effect analysis was presented. This was the same failure effect analysis that appeared in the preliminary reliability report PWA 2411 that was submitted to Grumman.

4.8.1 Power Generating Subsystem (PGS) (continued)

Pratt & Whitney's Reliability Plan PWA 2406 was reviewed and commented upon. The comments were discussed with P & WA representatives during their visit to GAEC on November 14 and 15, 1963 and Reliability Plan PWA 2406-Rev A was then submitted in accordance with these discussions.

During this report period, AiResearch division of the Garrett Corporation was selected as the cryogenic tankage supplier. Pre-contract negotiations are currently in progress to incorporate changes as defined by present design requirements. Yardney Electric Company has also been chosen as the battery vendor to supply the emergency backup and/or spiking batteries.

4.8.2 Power Distribution Subsystem

The inverter study was completed during this report period. This investigation considered all loads that require electrical power other than 28 VDC and included the glycal pump motors, suit fan motors, and cabin fan motor. Major objectives of this effort were to maximize reliability and minimize weight.

Many configurations were eliminated in the early stages of investigation because of basic operational deficiencies. The 5 remaining schemes are listed in the following table with their respective crew safety and mission success probabilities including earth launch equipment weight. Figures 4.8.1 to 4.8.5 illustrate configuration details where the loads supplied by each inverter are noted.

Configuration Reference No.	Crew Safety Probability	Mission Success Probability	Weight lbs. Earth Launch Eq. Weight
4B-2	.9999580	.9844712	117.0
4B-5	.9999580	.9911540	149.6
5B-2	.9999760	.9933082	125.9
14B-2	.9973793	.9840992	116.9
14B-5	.9999507	.9972756	157.7

Resulting from this study, configuration 5B-2 was chosen. This decision has precipitated the need for brushless d-c motor development program that will include stringent testing to assure that reliable operation is achieved. The scope of these tests will cover experimental, prototype, and production models.

4.8.2 Power Distribution Subsystem (continued)

Design verification testing will determine the performance of the motors under LEM environmental conditions. The reliability assurance phase of the design verification testing will then follow to gain confidence in the motor's ability to function as required throughout the LEM mission as well as providing some measure of the inherent strength margin under LEM environments. The last formal testing will be qualification testing where the test item will be subjected to environmental conditions which are in excess of the expected mission levels.

A trip to Goddard Space Flight Center was made to determine the stage of brushless d-c motor development at this facility. Results of this trip disclosed that Sperry Farragut Company is actively pursuing the true d-c motor concept under contract from Goddard. Details of this trip appear in LMO-550-175 and, in summary, points out that the only potential problem area uncovered was during vibrational testing where the light source failed. This light bulb is used in sensing motor position and in activating switching electronics.

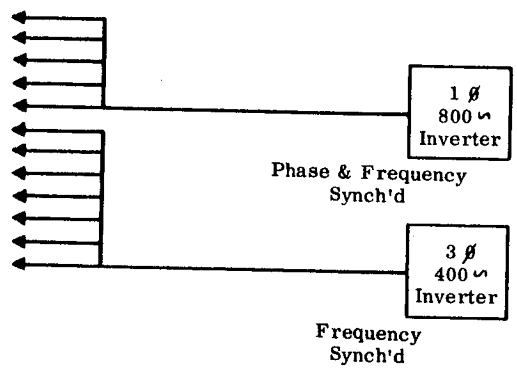
These same inverter configurations were also submitted as the PDS input to the weight-reliability effort. Reliability calculations were based on Mission Plan LPL-540-1 and amendment of Mission Plan LMO-540-149. Furthermore, the orbital contingency phase was deleted and a 4 hour lunar stay was considered to constitute mission success. Detailed break-down of subsystem operation was completed that allowed for phase-by-phase reliability predictions to be calculated. A number of converters and the environmental control system motors considered for the inverter effort were deleted from this prediction (loads 19 → 31 in Figure 4.8.1), and the reliability consideration for these items was covered in the respective subsystem. Results of the weight-reliability effort will provide the necessary data to establish the optimum PDS configuration when considered from the LEM system level. This program will continue during the next report period.

4.8.3 Vendor Procurement

Two specifications covering the back-pack battery charger and inverter are nearing release for bid competition. This will constitute completion of the major subportions of the EPS with respect to vendor procurement excluding the pyrotechnics.

Loads

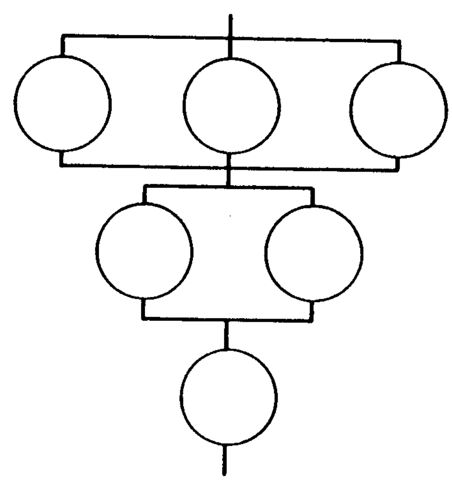
1. Attitude and Translation Controllers (CES)
2. Rate Gyro Assembly (CES)
3. Attitude Reference Assembly - AC (BUGS)
4. Flight Direction Attitude Indicator (FDAI) 8 Ball (Displays)
5. Rendezvous Radar (Ant. Servo and Synchro Motors)
6. Displays (other than FDAI)
7. Data Storage Equipment (Recorder)
8. Steerable Antenna
9. Lighting
10. Descent Engine Gimbal Actuators
11. Landing Radar (Tilt Mech.)
12. Rendezvous Radar (Servo Motor and Rate Gyros)
13. Attitude and Translation Control Assembly (CES)
14. In-flight Monitor (BUGS)
15. Programmer (BUGS)
16. Attitude Reference Assembly - DC (BUGS)
17. Guidance Coupler Assembly (CES)
18. Descent Engine Control Assembly (CES)
19. S-Band Power Amplifier
20. S-Band Transponder
21. VHF Transceiver
22. Pre-Modulation Processor
23. Television
24. Pulse Code Modulator and Time Equipment
25. In-flight Test Set
26. Landing Radar
27. Rendezvous Radar
28. Transponder



29. Glycol Pump Motor (brushless d-c)

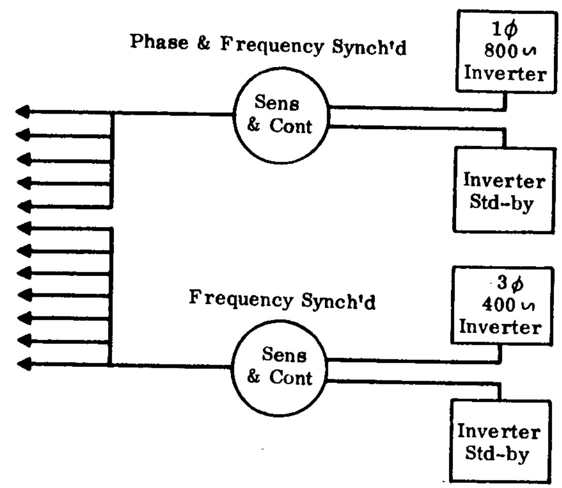
30. Suit Fan Motor (brushless d-c)

31. Cabin Fan Motor (brushless d-c)



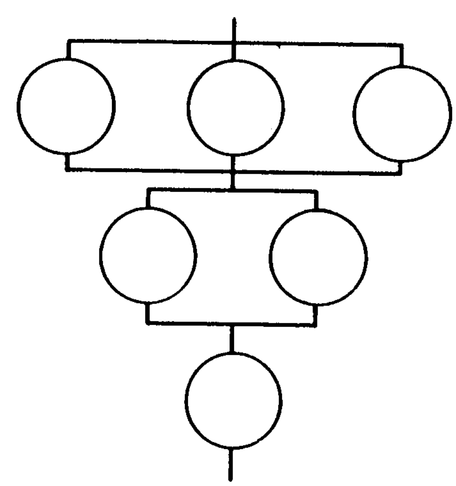
Loads 13 → 28 require power conversion within each box.

Figure 4.8.1
Configuration 4B 2



Loads

1. Attitude and Translation Controllers (CES)
2. Rate Gyro Assembly (CES)
3. Attitude Reference Assembly - AC (BUGS)
4. Flight Direction Attitude Indicator (FDAI) 8 Ball (Displays)
5. Rendezvous Radar (Ant. Servo and Synchro Motors)
6. Displays (other than FDAI)
7. Data Storage Equipment (Recorder)
8. Steerable Antenna
9. Lighting
10. Descent Engine Gimbal Actuators
11. Landing Radar (Tilt Mech.)
12. Rendezvous Radar (Servo Motor and Rate Gyros)
13. Attitude and Translation Control Assembly (CES)
14. In-flight Monitor (BUGS)
15. Programmer (BUGS)
16. Attitude Reference Assembly - DC (BUGS)
17. Guidance Coupler Assembly (CES)
18. Descent Engine Control Assembly (CES)
19. S-Band Power Amplifier
20. S-Band Transponder
21. VHF Transceiver
22. Pre-Modulation Processor
23. Television
24. Pulse Code Modulator and Time Equipment
25. In-flight Test Set
26. Landing Radar
27. Rendezvous Radar
28. Transponder



29. Glycol Pump Motor (brushless d-c)

30. Suit Fan Motor (brushless d-c)

31. Cabin Fan Motor (brushless d-c)

Loads 13→28 require power conversion within each box.

Figure 4.8.2
Configuration 4B-5

Loads

1. Attitude and Translation Controllers (CES)
2. Rate Gyro Assembly (CES)

3. Attitude and Translation Control Assembly
4. Guidance Coupler Assembly
5. Descent Engine Control Assembly

6. Flight Direction Attitude Indicator (FDAI) 8 Ball (Displays)

7. Rendezvous Radar (Ant. Servo and Synchro Motors)

8. Displays (other than FDAI's)
9. Data Storage Equipment (Recorder)
10. Steerable Antenna
11. Lighting
12. Descent Engine Gimbal Actuators
13. Landing Radar (Tilt Mech)
14. Rendezvous Radar (Servo Motors & Rate Gyros)

15. Attitude Reference Assembly - AC (BUGS)

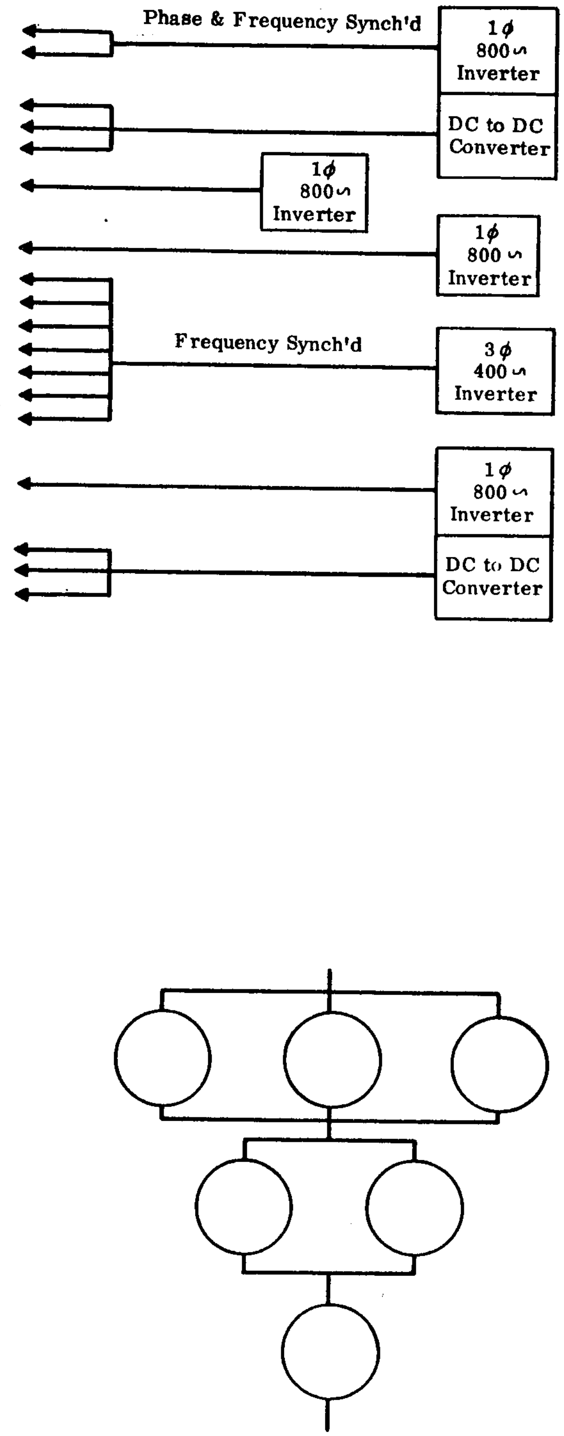
16. Attitude Reference Assembly - DC (BUGS)
17. In Flight Monitor
18. Programmer

19. S-Band Power Amplifier
20. S-Band Transponder
21. VHF Transceiver
22. Pre Modulation Processor
23. Television
24. Pulse Code Modulator and Time Equipment
25. In-flight Test Set (Instrumentation)
26. Landing Radar
27. Rendezvous Radar
28. Transponder

29. Glycol Pump Motor (brushless d-c)

30. Suit Fan Motor (brushless d-c)

31. Cabin Fan Motor (brushless d-c)



Loads 19→28 require power conversion within each box.

Figure 4.8.3
Configuration 5B-2

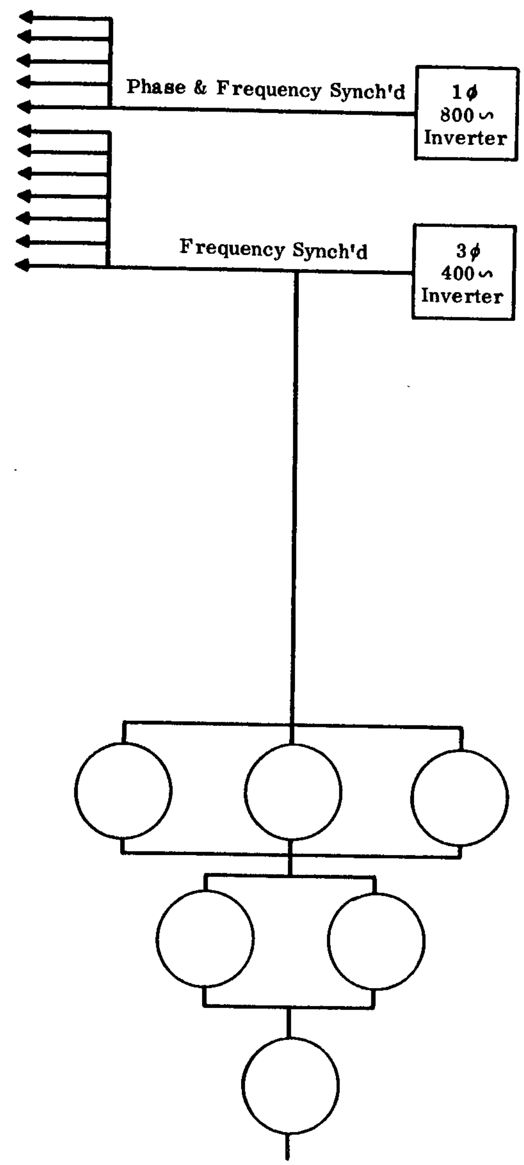
Loads

1. Attitude and Translation Controllers (CES)
2. Rate Gyro Assembly (CES)
3. Attitude Reference Assembly - AC (BUGS)
4. Flight Direction Attitude Indicator (FDAI) 8 Ball (Displays)
5. Rendezvous Radar (Ant. Servo and Synchro Motors)
6. Displays (other than FDAI)
7. Data Storage Equipment (Recorder)
8. Steerable Antenna
9. Lighting
10. Descent Engine Gimbal Actuators
11. Landing Radar (Tilt Mech.)
12. Rendezvous Radar (Servo Motor and Rate Gyros)
13. Attitude and Translation Control Assembly (CES)
14. In-flight Monitor (BUGS)
15. Programmer (BUGS)
16. Attitude Reference Assembly - DC (BUGS)
17. Guidance Coupler Assembly (CES)
18. Descent Engine Control Assembly (CES)
19. S-Band Power Amplifier
20. S-Band Transponder
21. VHF Transceiver
22. Pre-Modulation Processor
23. Television
24. Pulse Code Modulator and Time Equipment
25. In-flight Test Set
26. Landing Radar
27. Rendezvous Radar
28. Transponder

29. Glycol Pump Motor (a-c Motors)

30. Suit Fan Motor (a-c Motors)

31. Cabin Fan Motor (a-c Motors)

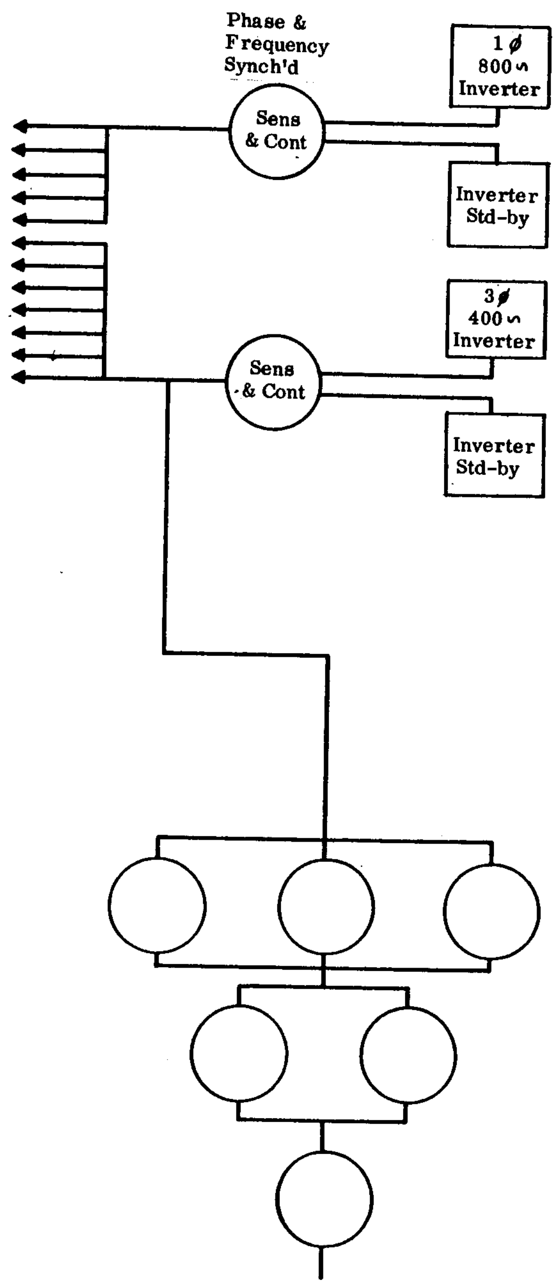


Loads 13→28 require power conversion within each box.

Figure 4.8.4
Configuration 14B-2

Loads

1. Attitude and Translation Controllers (CES)
2. Rate Gyro Assembly (CES)
3. Attitude Reference Assembly - AC (BUGS)
4. Flight Direction Attitude Indicator (FDAI) 8 ball (Displays)
5. Rendezvous Radar (Ant. Servo and Synchro Motor)
6. Displays (other than FDAI)
7. Data Storage Equipment (Recorder)
8. Steerable Antenna
9. Lighting
10. Descent Engine Gimbal Actuators
11. Landing Radar (Tilt Mech.)
12. Rendezvous Radar (Servo Motor and Rate Gyros)
13. Attitude and Translation Control Assembly (CES)
14. In-flight Monitor (BUGS)
15. Programmer (BUGS)
16. Attitude Reference Assembly - DC (BUGS)
17. Guidance Coupler Assembly (CES)
18. Descent Engine Control Assembly (CES)
19. S-Band Power Amplifier
20. S-Band Transponder
21. VHF Transceiver
22. Pre-Modulation Processor
23. Television
24. Pulse Code Modulator and Time Equipment
25. In-flight Test Set
26. Landing Radar
27. Rendezvous Radar
28. Transponder
29. Glycol Pump Motor (a-c Motors)
30. Suit Fan Motor (a-c Motors)
31. Cabin Fan Motor (a-c Motors)



Loads 13→28 require power conversion within each box

Figure 4.8.5
Configuration 14B-5

4.8.4 Pyrotechnics Subsystem

The pyrotechnic subsystem consists of batteries that will store the energy required to activate the individual devices by proper use of a selector and/or timing device, and the distribution portion of the subsystem.

Thirteen pyrotechnic power supply configurations have been investigated and reliability predictions calculated. This study considered the various energy sources available that could be employed to activate the pyrotechnic devices located within the various subsystems. Reference may be made to LED-550-13 for the details of the study that concluded in recommending redundant batteries with the capability of switching to the primary power supply in the event of battery failure.

4.8.5 Subcontractor Documents Submitted and Reviewed

1. Preliminary Reliability Report for the PCGA-1 LEM Fuel Cell Assembly, PWA-2411, Pratt & Whitney Aircraft, November 1963.
2. Reliability Plan for LEM Fuel Cell Assembly, PWA-2406, Pratt & Whitney Aircraft, October 1963.
3. Reliability Plan for LEM Fuel Cell Assembly, Rev. A, PWA-2406, Pratt & Whitney Aircraft, December 1963.

TABLE 4.8.1

Phases / Config	1	2	3	4	5	6	7	8	9	10	Total
1	.991976 .991976	.999984 .999983	.999759 .999758	.999908 .999907	.999969 .999969	.999963 .999631	Phase 7 is 5-23 hr. Lunar stay and is not computed for mission success.	.999999 .999961	.999999 .999994	.999999 .999996	.991183
2	.991541 .991541	.999984 .999983	.999759 .999731	.999908 .999897	.999969 .999965	.999631 .999588		.999994 .999994	.999994 .999994	.999996 .999996	.990699
3	.991776 .991776	.999984 .999757	.999759 .999746	.999941 .999902	.999969 .999967	.999632 .999611		.999999 .999993	.999999 .999999	.999999 .999999	.990764
4	.990740 .990740	.999982 .999650	.999728 .999638	.999896 .999890	.999965 .999963	.999584 .999563		.999999 .999993	.999999 .999999	.999999 .999999	.989452
5	.976611 .976611	.999955 .999955	.999295 .999212	.999730 .999728	.999910 .999909	.998922 .999527		.999999 .999999	.999999 .999997	.999999 .999999	.974984
6	.978867 .978867	.999959 .999959	.999364 .999282	.999757 .999754	.999919 .999918	.999028 .999018		.999999 .999999	.999999 .999999	.999999 .999999	.976845

Config. 1: 3 FCA + Emergency Battery
Staged O_2; 2 Ascent, 1 Descent
Staged H_2; 2 Ascent, 1 Descent

Config. 2: 3 FCA
Staged O_2; 2 Ascent, 1 Descent
Staged H_2; 2 Ascent, 1 Descent

Config. 3: 2 FCA + Emergency Battery
Staged O_2; 2 Ascent, 1 Descent
Staged H_2; 2 Ascent, 1 Descent

Config. 4: 2 FCA + Emergency Battery
Staged O_2; 2 Ascent, 1 Descent
Staged H_2; 1 Ascent, 1 Descent

Config. 5: 1 FCA + Emergency Battery
Staged O_2; 2 Ascent, 1 Descent
Staged H_2; 1 Ascent, 1 Descent

Config. 6: 1 FCA + 2 Emergency Batteries
Staged O_2; 2 Ascent, 1 Descent
Staged H_2; 1 Ascent, 1 Descent

NOTE: The top number indicates the per phase reliability, where as, the bottom number indicates the conditional probability of phase success given that you have reached that phase. The total mission success reliability is the product of all conditional per phase reliabilities.

4.9 INSTRUMENTATION SUBSYSTEM

Efforts were made to carry out the possible studies and reliability analysis of this subsystem on the basis of definitions and related ground rules given in Mission Plan LPL-540-1.

The two main sections of the subsystem are the Scientific Instruments and the Operational Instrumentation. Technical information for the first section is not available now. Information exists for only part of the second section.

Efforts continue for gathering technical and reliability data.

4.9.1 Operational Instrumentation Section

Certain assumptions were made for this analysis concerning the equipment of the above section and its interface with the other subsystems.

The equivalent time, duty cycle, and apportioned reliabilities were calculated and reliability estimates were made for equipment that have specifications, LVR's, and design information. The results of this study are stated in LED-550-16.

4.9.1.1 Sensors

Specific design information for the sensors does not exist at present; however, specifications, LVR s, and ground rules for their selection are in preparation.

The reliability degradation, due to the large sensor number, is apparent, since for functional success all of these must be in series. Special attention must be paid in defining this number and, therefore, in defining the measurements requirement. Recognizing the need for prudent measurement selection, ground rules will be prepared on basis of which an optimum measurement list will be reached.

4.9.1.2 Signal Conditioning Unit (SCU)

The design requirements for the SCU on a general frame have been well-defined and revisions and adjustments to the changing subsystem requirements have been made. Specifications, vendor requirements, and ground rules for device selection and device qualification program, where necessary, are in their final phase of completion.

Efforts of technical and reliability data collection continue. Results of these activities are presented in LED-550-16. Reliability data given in this reference are based on the information available at present.

4.9.1.3 Pulse Code Modulator PCM

Most of the design information exists with the exception of circuit, component, cabling, and connector detail.

All studies and estimates were based on technical information given by Radiation, Incorporated proposal R1-8674E-4-21 and the failure rates gathered by this department.

Detailed results of the studies are given in LED-550-16.

The above assembly is referred to as PCMTE, because PCM and the Timing Equipment are housed in one box. For reliability study purposes, the two assemblies will be treated separately.

4.9.1.4 Data Storage Equipment (DSE)

The efforts were directed towards analyzing the DSE requirements and carrying out reliability estimates for all subassemblies involved. Some interface electronics and mechanical components were exempted for lack of design and failure rate information.

The study was based on Leach technical proposal for DSE No. 231396 and on failure rate list produced by the Reliability Department.

The results of this study are presented in LED-550-16.

4.9.1.4 (continued)

Due to the possible weight difficulties, three alternatives are considered. The first is the DSE nominal configuration, i.e., data and voice storage capabilities on board the LEM. The second is the voice stoage on board the LEM and data storage on board the CM. The third is only the voice storage capability on board the LEM.

The two last configurations introduce some degradation due to the greater complexity of the second and the lack of data storage capability of the third.

However, future studies will analyze these configurations for comparison and possible need of trade-offs.

4.9.1.5 Emergency Detection Equipment (EDE)

The efforts for the EDE are at a standstill awaiting directions from NASA/GAEC Systems group.

The duty cycle and the equivalent operating time for this equipment have been derived on the basis of the Mission Plan LPL-540-1 for the entire mission profile.

Reliability analysis and estimates for the two configurations that resulted from previous efforts were completed for comparison purposes.

4.9.1.6 Caution and Warning Equipment (C&WE)

This assembly is in the state of philosophy and derivation of ground rules governing the hardware requirements for the C&WE.

The specifications and LVR's are in the phase of completion.

On the basis of these documents and the vendor inputs, a reliability analysis will be possible on terms of more specific information.

4.9.1.7 On-Board Checkout Equipment (OBCE)

This assembly is in the same status as the C&WE. The studies that will be performed on the On-Board Checkout Equipment are the same as those performed on the C&WE and will be performed one month after the C&WE.

4.10 STRUCTURES SUBSYSTEM

4.10.1 General

Reliability studies were performed on Ascent - Descent Stage Separation Systems, Engine Mounts, Hatches, Elapsed Time Indicators, and Weights - Reliability trade offs. The following paragraphs summarize the efforts expended on these studies. For a summary of the apportioned and estimated reliabilities of the major structural units, see Table 4.10.1.

TABLE 4.10.1

STRUCTURE SUBSYSTEM WEIGHT - RELIABILITY SUMMARY

EQUIPMENT	RELIABILITY				WEIGHT	
	APPORTIONED		ESTIMATED		APPOR.	EST.
	Rm	Rs	Rm	Rs		
LEM STRUCTURE	.999628	.999956	.999978	.999978	1220	1687
LANDING GEAR	.999883	.999995	.999998	.999999+	295	468
ASCENT-DESCENT STAGE SEPARATION SYSTEM	.999994	.999994	.999999 *	.999999 *	18.3	29.0
DOCKING MECH	.999990	----	----	----	----	----
TOTAL	.999495	999945	----	----	----	----

*Electrical and Fluid Disconnect System Not Included.

4.10.2 Ascent - Descent Stage Separation System

A quantitative configuration analysis was performed on six of the more promising proposed ascent - descent stage separations systems; see reference "a". The six systems all employing dual initiators were:

1. A redundant explosive bolt system.
2. An explosive bolt and explosive nut system.
3. A sealed actuator lock system.
4. A sealed actuator lock with an explosive nut system.
5. Gas operated actuator, ball lock system.
6. The North American Launch Escape Tower explosive bolt-shaped change system.

This analysis was a definite help in eliminating some of the less reliable and sometimes heavier configurations; one in particular was a favorite prior to starting this analysis. Table 4.10.2 summarizes the results of this study. Columns 6, 7 and 8 of this table, titled "Negative Reliability Factors" are used to break numerical ties. These columns represent unreliability factors which will tend to reduce the reliability of a system. A check mark denotes such an unreliability factor, a zero denotes no such factor. If two or more systems are numerically equal, the system with the least number of check marks is considered to be the most reliable. For example; the bolt and nut system #2 has a check mark in Table 4.10.2, Mechanical Complexity. This is because after the pyrotechnics fire there are a number of moving parts of the nut involving sliding, camming and clearing actions. The NAA-LES system #6 on the other hand has no such negative reliability factors. Thus system #6 is rated higher than #2, although they both show the same numerical reliability.

Other Studies

Various qualatative studies have been made on other possible separation system. A case in point is and explosive bolt which is triggered by MDF (Mild Detonating Fuse) instead of a bridgewire. A qualitative examination of this system indicated that reliability would be enhanced at virtually no weight penalty by using a closed loop, i.e., 360° of MDF as opposed to the original 270°. The 360° approach was finally decided upon for this possible system. A sketch of the 270° and 360° system appears in Figure 4.10.1. The 360° system has the advantage over the 270° system of being able to have a break occur anywhere in the MDF bolt loop and still not result in a bolt (or nut) failing to receive its separation signal.

TABLE 4.10.2

Summary - Predicted Reliability

& Weight of 6 Separation System

System					Negative Reliability Factors * not in Numerical Prediction			
Name	Scheme Number	Unreliability 10^6 Missions	Reliability	Weight (lbs.)	Mech. Complexity (M)	One Release Joint vs. Two (r)	Susceptibility To Common Failure Mode (C)	Reliability Rating (1-Best)
S TL Bolt	1	.64	.99999936	1.528	0	0		3
Bolt & Nut	2	.64	.99999936	2.188	✓	0	0	4
Sealed Release Dual	3	.84	.99999916	2.296	✓	✓	0	5
Sealed Release Triple	4	.0003	.99999999	2.896	✓	0	0	1
Pelmec Ball Lock	5	1.06	.99999894	5.458	✓✓	✓	0	6
NAA-LES	6	.64	.99999936	11.180	0	0	0	2

* Used to break numerical ties to establish rating.

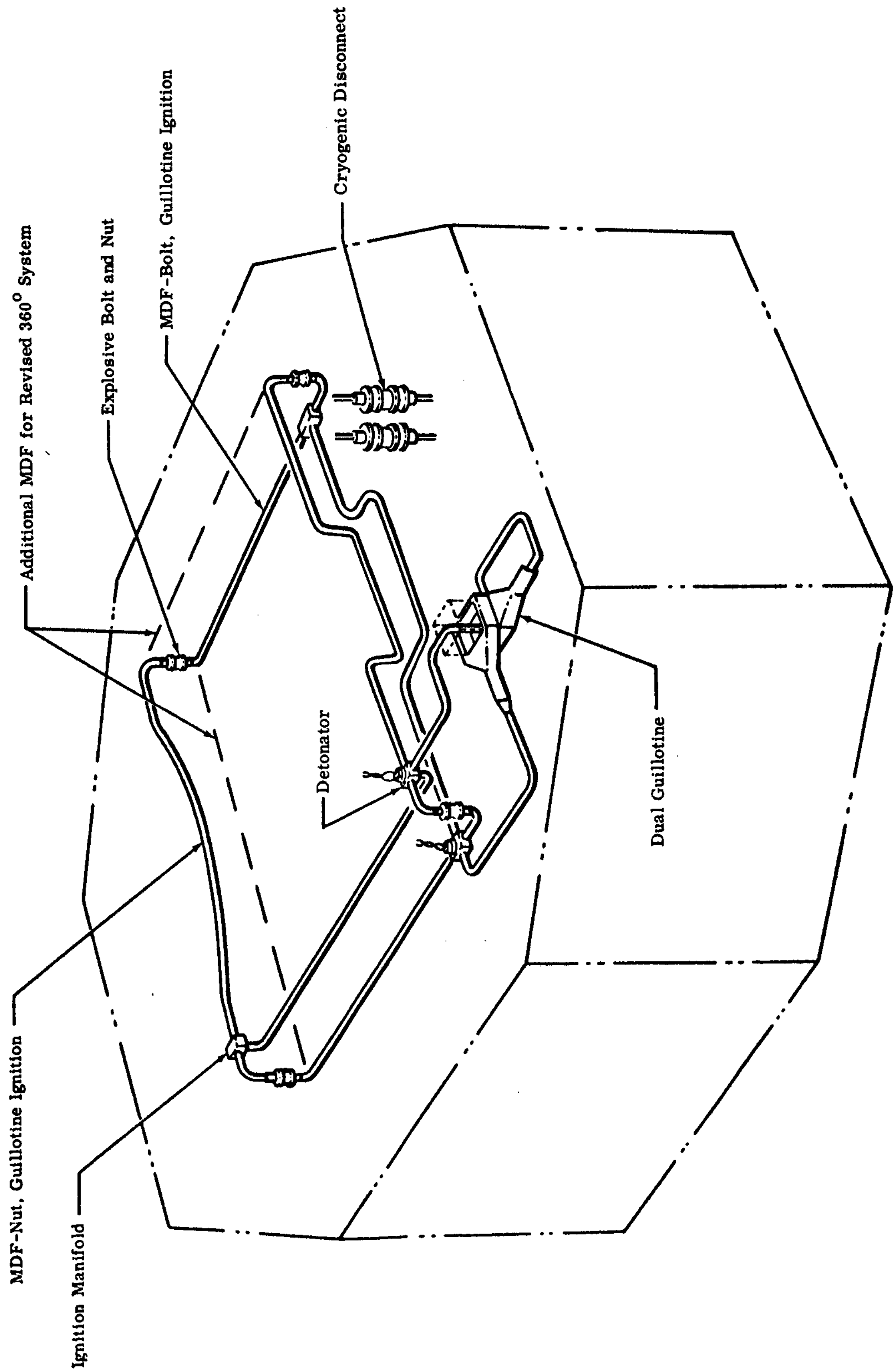


Figure 4.10.1
Installation - MDF Ascent-Descent Stage Separation System

Future Work

Work on these and other separation systems is continuing and will be reported on in the near future.

Reference

(a) LED-550-9 , dated 9 September 1963

4.10.3 Descent Engine Mount

A reliability analysis was performed on a 6 and 8 bar engine mount configuration. The following ground rules applied: 6 bar system - for success at least 3 of 4 bars working on one side of the gimbal, plus 2 of 2 working on the other side; 8 bar system - for success at least 3 Of 4 working on one side of the gimbal plus 2 of 4 on the other side.

Considering the engine mount alone, the reliability analysis revealed that the 8 bar system is superior to the 6 bar system. also, according to the ground rules used, the 8 bar system is more redundant. However, there are other factors associated with the engine mount that must be considered. For instance, can the added redundancy of the 8 bar system be made use of since it may not be fully redundant? This would occur during the brief starting period if the engine were started at full throttle. The full throttle loads plus the overshoot during starting result in the peak loads. In addition, it appears that the 8 bar system may place loads on the engine that the 6 bar does not.

The engine mount problems are still being studied.

A sketch of the 6 and 8 bar systems appear in Figure 4.10.2.

4.10.4 Hatches

The previous hatch concept was to have each of the locking lugs independantly locked by a nut-bolt arrangement operated by a long detachable extension tool. After conducting mock-up tests, it was felt that this was a difficult operation for the astronaut to perform. Accordingly the design was revised to the current concept of operating all the lugs from a single more accessable location. This should help overall reliability (taking into account factors such as, accessability, ease of operation, lesser probability of injuring the spare suit, etc.) even though the later locking mechanism is more complex than the former locking arrangement.

4.10.5 Elapsed Time Indicators

The Elapsed Time Indicators may be used on LEM. An estimate was made of the number of elapsed time indicators required, listing quantity, priority and types. The types of indicators are cycle, hourly, and calender. These indicators will enhance reliability by providing a record of the equipment usage before flight. It will also help supply improved failure rate data. From 7 to 18 indicators will be required if they are used.

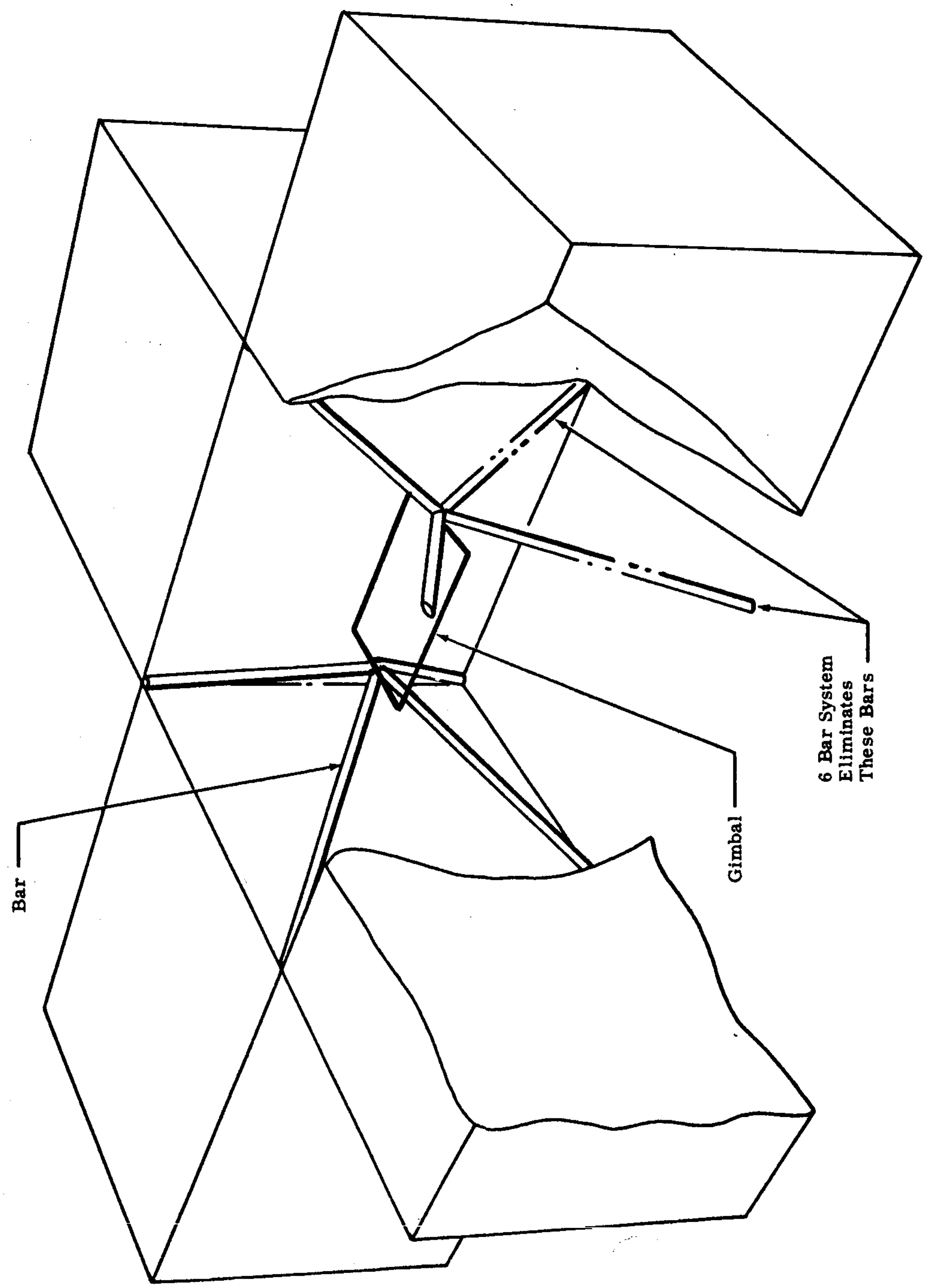


Figure 4.10.2
Six and Eight Bar Descent Engine Mount

4.10.6 Weight - Reliability Study

A weight reliability study was conducted on all applicable structural areas to effect judicious weight reliability trade offs. This study again pointed out that the lighter system is not necessarily less reliable.

4.10.6.1 Separation System

One of the areas pursued was the separation system. A reliability prediction and weight estimate (Ref. Para. 4.10.2) was performed on six of the most promising separation system. Table 4.10.2 from reference "a" summarizes the weights and reliabilities of this study.

Future Work

Work on existing and new separation systems is continuing and the weight reliability study will be continued with these new studies.

4.10.6.2 Structure and Capsule

The two basic approaches to trading off weight and reliability are:

a) Riveted vs. welded cabin structure.
b) Increased design margins.

The welded cabin structure is virtually dictated by the low leakage rate requirements. While it is felt that the riveted structure would be structurally more reliable (at say a 20% weight penalty) it would be more unreliable from the leakage viewpoint. The desired maximum leakage rates of the riveted structure would probably be exceeded.

The choice of welded structure is based on years of experience both with riveted pressurized fuselages, and with welded structures. It is noteworthy that Gemini, Mercury and Apollo all use welded structures.

The second basic method of effecting a weight reliability trade off is by changing the structural design margin. This will affect weight in an approximate linear fashion. A minimum design margin was selected that was felt to be consistant within the state-of-the-art and within bounds of what experience dictates. Considering the vital role of the primary structure, it is felt that this is not a wise area for further trimming of weight at the expense of reliability,

4.10.6.3 Landing Gear

The landing gear is basically a piece of structure with design margins and other requirements (such as vertical landing velocity, horizontal velocity, stowage requirements, lunar surface characteristics, etc.,) virtually dictating the structural requirements and much of the configuration; hence the basic weight and reliability of the gear configuration, assuming a four legged gear. The selection of the four legged gear configuration was discussed in previous quarterly reports. The effect on weight and reliability was also discussed. Accordingly, as with the basic structure, it is felt that the weight-reliability efferts should be performed in more fruitful areas since the aforementioned determines weight and reliability of the basic gear.

When the basic gear becomes more definitized a weight-reliability study of the more detailed items, such as various extension and locking systems, should prove worthwhile relibility wise and weight wise.

4.11 CREW PROVISIONS SUBSYSTEM

4.11.1 General

A reliability effort was made in the following areas; lighting, weight-reliability, and elapsed time indicators. The following paragraphs summarize the efforts expended in these areas.

4.11.2 Lighting

Electroluminescent (EL) lighting has been selected as the lighting technique for the crew compartment panel lighting. Reference meeting at NASA Manned Spacecraft Centers, Houston, 24 September 1963. Incandescent cabin flood lights act as a degraded back up for the panel lights, in addition to their normal cabin lighting function.

The panel lighting choice was between incandescent and EL. The EL was selected because of the following advantages:

1) Reliability - while more data is required to make statements of confidence, it appears that the most promising system for panel lighting is the EL system. This system has the advantage over incandescent, of generally not having sudden or complete failures. The light just gradually gets dimmer over a long time period. It does not go out suddenly as is often the case with an incandescent bulb filament failure In addition, wear-out is not an abrupt failure, but is also a gradual dimming, which can be observed without the aid of instruments. It is also felt that the EL will be less prone to failure in many of the environmental extremes.

2) Weight and Power - About 200 watts would be required to run the incandescent panel lights, whereas 20 - 50 watts would be required for the EL. While the systems themselves have virtually no weight difference, weight is saved with the EL system due to the fuel saved (H_2 and O_2 for the fuel cell) with the lower power requirements of the EL. Using a fuel-power ratio of 3 pounds of fuel per kilowatt hour and a 50 hour mission, gives a fuel weight of 30 pounds for the incandescent system and 3 to 7.5 pounds for the EL, a significant weight saving for the EL.

In addition to a literature search, severe tests were run at Grumman on one hundred EL lights from five (5) different manufacturers. Details are recorded in GAEC report LTR-340-2 (SER-10-1) dated 21 October 1963. The few "failures" that occured, were of the gradual type; all of the parts that "failed" were manufactured by two of the five vendors. It is believed that the five vendors are not all equally advanced in the state of the art. The most likely problem areas are temperature and radiation.

4.11.3 Weight-Reliability Study

A weight reliability study was conducted on all applicable areas in the crew provisions systems. In virtually all cases, the nature of the equipment or system was such that they did not lend themselves to numerical reliability predictions. For instance, numerically how much reliability is lost by reducing the content of the first aid kit or reducing the water or food. Accordingly, the crew provisions weight-reliability study indicated "increase" or "decrease" of reliability without reference to a numerical gain or loss. Refer to Table 4.11.1 for the results of this study.

It was found that weight was saved in two areas, i.e., crew provisions and electrical power. The fact is that a particular scheme or device may not effect any weight saving in itself for the crew provision system, but might for the electrical system. Table 4.11.1 breaks the weight saved into these two categories. An example of this is the first item listed in Table 4.11.1, light color and brightness.

The paragraphs of Section 4.11.2 on lighting apply to the Weight-Reliability Study. It is believed that the selected system (EL) is the more reliable and lighter system.

4.11.4 Elapsed Time Indicators

Elapsed Time Indicators may be used on LEM. An estimate was made of the number of Elapsed Time Indicators required, listing quantity, priority, and types. The types of indicators are cycle, hourly, and calender. These indicators will enhance reliability by providing a record of the equipment usage before flight. It will also help supply improved failure rate data. From one to eight indicators will be required, if they are used.

TABLE 4.11.1

CREW PROVISIONING WEIGHT-RELIABILITY STUDY

Configuration	Weight	Weight Saved (lbs.) Crew Provisions	Weight Saved (lbs.) Electrical* Power	Reliability	Remarks
Lighting Color (with 2 central inverters): #1 - red - bright #2 - red - #3 - white - #4 - green -	 38.77 32.66 29.47 29.00	 negligible negligible negligible negligible	 0 6.11 9.30 9.77	Increasing	Reliability For Human Factors - No Change Or Slight Decrease
Replace Thumbwheels and Lights with Knobs and Lights	-	none	1.02	Increase (no gears)	Same As Above
Silhoutte Lighting of Panels for: System #1, System #4	-	none	7, 2	No Change	Same As Above
Eliminate Some Lighting at Flight Engineering Station, if only Pilot has Flight Controls: System #1, System #4	-	2.5, 2.5	1.8, .7	Decrease Piloting Reliability	-
Eliminate Back-up Flood and Area Lighting:					
System #1		6.73		Decrease	
System #4		5.68		Decrease	
But Add "Flashlight"	-	-0.5	-	Slight Decrease	-
Omit External Docking Lights (Dock In Sunlight or Earthlight)	-	4	-	Decrease	-
Omit One 5-10 mile Recognition Light (Existing Radar Back-Up)	-	2	-	Decrease	-
Omit Pyrotechnic Landing Lights (Use Earthshine)	-	10	-	Decrease	-

TABLE 4.11.1

CREW PROVISIONING WEIGHT-RELIABILITY STUDY

(continued)

Configuration	Weight	Weight Saved (lbs.) Crew Provisions	Weight Saved (lbs.) Electrical* Power	Reliability	Remarks
Flood Lighting Only Instead of Electro-Luminesant Lighting	-	0	-	Decrease	-
Omit Crew Seats and Use Restraint System	-	60	-	Increase	-
One Day Water Supply, Food Supply - Instead Of Two	-	10 3 3/4	- -	Decrease Decrease	- -
Lightweight Space Suit	-	2	-	Decrease	-
Lightweight Waste Management	-	1/4	-	Decrease	-
Omit First Aid Kit	-	2	-	Decrease	-
Controlled Diet Prior To Flight	-	-	-	-	-
Omit Disinfectant Bottle	-	0.5	-	Decrease	-
Omit Vomitus Removal Device	-	0.4	-	Decrease	-
Omit Emergency O_2 Supply	-	5.4	-	Decrease	-
Omit Spare Parts For PLSS and Suit	-	26.0	-	Decrease	-
Omit Tool Kit and Tool Belt	-	4.0	-	Decrease	-
Omit Space Suit Repair Kit	-	3.0	-	Decrease	-

TABLE 4.11.1

CREW PROVISIONING WEIGHT-RELIABILITY STUDY

(continued)

Configuration	Weight	Weight Saved (lbs.)		Reliability	Remarks
		Crew Provisions	Electrical* Power		
Shorten Tunnel:					
Length	-		-		
Diameter	-		-	Decrease	-
Leave Following Items On Moon:					
Fical Waste	-		-	See Remarks	Reliability Increased Slightly Because Of Increased Thrust/Wt. Ratio Reliability or Desire-ability Of Moon De-creased
Urine	-		-		
Extra Vehicular Boots	-		-		
Thermal Gloves and Garments	-		-		
Radiation Dosimeter	-		-		
Empty LiOH Canister	-		-		
Still Camera	-		-		
2800 Calories/Day Instead of 3200	-		-	Decrease	-

5. RELIABILITY ASSURANCE PROGRAM

5.1 SUMMARY OF ACTIVITIES

Reliability Test activities during this reporting period were primarily concerned with:

a) Procurement document preparation.

b) Proposal review and vendor evaluation.

c) Vendor negotiations.

d) Review of vendor documents, including Reliability Program Plans and General Test Plans.

e) Review of in-house test plans.

f) Statistical design of tests.

g) Design feasibility test monitoring.

h) Specification amendment activity.

i) General test planning activity.

The above activities will be discussed in more detail in other areas of this section.

During this past quarter, Grumman has experienced some difficulty in gaining NASA approval of several equipment specifications due to lack of a mutual understanding of the aims and purposes of the Reliability Assurance Program. Accordingly, steps have been taken by Grumman and NASA to reconcile these differences and the results of these negotiations will be published in the next Quarterly Reliability Status Report. In addition it is expected that once agreement is reached on these subjects, it will be possible for GAEC to submit a Reliability Program Plan which will meet with NASA approval.

Considerable effort was expended in incorporating specific Reliability Boundary Conditions into each equipment specification. The RB Table constitutes one complete mission simulation for a flyable piece of hardware. The incorporation of the table was found to be a practical necessity in order to eliminate the divergent opinion among vendors as to what constituted a mission simulation. The stress-to-failure tests of the development program are preceded by one mission simulation in accordance with RB Table plus a check of the most severe conditions of the qualification tests. Because of the weight being placed on the results of the stress-to-failure tests, it is important that the preceding mission simulation be well defined. As a result the RB Table was generated.

5.1 SUMMARY OF ACTIVITIES (continued)

The generalized format for the elimination of the statistical analysis by Weibull, plus the Reliability Boundary Table was circulated to the Project in LAV-550-12 dated 18 October 1963. The updated Reliability "working format" for the table is shown in Appendix A. It may be noted that the "working format" includes several other changes which were based on the November 15, 1963 release of the revised "Design Criteria and Environments" Report (LED-520-18). and LAV-470-2, 21 Nov. 1963.

Not shown in Appendix A is the simplified component mission simulation conditions. These conditions are employed by LEM Project for Reliability Assurance and Qualification Tests of small components whose location in the LEM is obscure and whose micro-environments cannot be defined until after the LTA tests.

A concerted effort was made to update all subsystem PERT diagrams to include the milestones and constraints of the reliability assurance tests of the development test program. In general, the effect of this activity was to increase the degree of regimentation in development test scheduling without causing downstream slippage in the qualification tests and hardware deliveries.

The PERT activity was concurrent with, and in support of the Apollo Integrated Test Panel investigation. This Panel, consisting of representatives from NAA, GAEC, and MIT was formed by direction of NASA to coordinate launch dates, hardware deliveries and facility availability for the Apollo Ground and Flight Test program. The results of this team effort will be available during the next reporting period.

In the area of training, several presentations of the LEM Reliability Assurance Program were given to subsystem engineers in order to permit them to better understand the underlying philosophy of the stress-to-failure tests.

5.1.2 Criticality Effects on the Test Program

The previous Reliability Quarterly Status report discussed the use of Criticality as a criterion for establishing the quantity of hardware for Reliability Assurance Tests. It was then stated that Class I (Crew Safety) equipment would require four units for these tests, Class II (Mission Success) would require three, and Class III, two. It was also stated that in general, components, even though redundant, would

5.1.2 Criticality Effects on the Test Program (continued)

receive the same rating as the subsystem, and that state-of-the-art considerations, complexity, and other pertinent factors might also affect the hardware requirements. Accordingly, a list of equipment with their hardware quantities for test has been included with this report in Appendix B. These hardware quantities are specified as a minimum in all new procurement documents and will be specified in the amendments of existing contracts. The Criticality Ratings indicated in the table represent the present status of the LEM equipment. As configuration and design progresses, this list will be updated.

5.1.3 Test Program Progress

The status of vendor test programs is presented in Table 5-1. It is to be noted that the majority of contractors are still in the design feasibility phase of their programs. The NS (not started) notation is used to indicate that no official documentation has been received by Grumman that alludes to the presence of test plans. However, it is apparent from the depth to which testing is covered in contract negotiations, that considerable test planning is in progress.

5.1.4 Test Document Review

Vendor test documentation has been confined so far to General Test Plans, test sections of Program Plans, and Monthly Progress Reports. However, Reliability has reviewed and signed off on a multitude of in-house Design Feasibility test plans.

The role of the Reliability Test in these reviews has been to make constructive comment where indicated; take note of potential sources of backup data for reliability analyses, recommend statistical design and analyses where appropriate, and catalog the pertinent data for the Test I.D. program.

A list of all test plans and reports (including Vendor documents) is contained in Appendix C. This list will be updated in subsequent reports.

TABLE 5-1

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Communications					
S-Band Steerable Antenna	CV	Vendor to RCA	NS	NS	
S-Band Erectable Antenna	CV	RCA	NS	NS	
S-Band Transceiver	CV	Vendor to RCA	NS	NS	Common Usage
S-Band Power Amp.	CV	Vendor to RCA	NS	NS	Common Usage
S-Band Diplexer	CV	RCA	NS	NS	
VHF Transceiver	CV	RCA	NS	NS	

LEGEND

C - Completed
CB - Completed, Bidder Proposals Under Evaluation
CV - Completed, Vendor Negotiations in Progress
CN - Completed and Negotiated

DF - Design Feasibility
IP - In Progress
NA - Not Applicable
NS - Not Started
UP - Under Preparation

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Communications (continued)					
Premodulation Processor	CV	Vendor to RCA	NS	NS	Common Usage
Audio Center	CV	Vendor to RCA	NS	NS	Common Usage
VHF Diplexer	UP	-	NS	NS	
S-Band Switch	UP	-	NS	NS	
VHF Switch	UP	-	NS	NS	
RF Cables & Conn.	NA	NA	NS	NS	
VHF In-Flight Antenna	NA	NA	NS	NS	
S-Band In-Flight Antenna	NA	NA	NS	NS	
Crew Provisions					
Incandescent Lamps	NA	NA	C	IP	28V Lamp d.f. Tests
E.L. Lamps	NA	NA	C	IP	Electroluminescant Lamp Feasibility Test

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Status of Test Program: Subcontractor (or Selected for) Negotiations	Status of Test Program: Test Plans	Status of Test Program: Tests	Remarks
Crew Provisions (continued)					
Lighting	NA	NA	C-Preliminary Gen. Plan.	DF-IP	Reliability Inputs Incorporated.
Seats	NA	NA	C-Preliminary Gen. Plan.	NS	Reliability Inputs Incorporated.
Control & Displays					
Display Panel	NA	NA	C	NS	Feasibility Tests of Display Panel.
Instrumentation Clamps	NA	NA	C	NS	Investigation of Clamping Techniques
Switchs	NA	NA	C	IP	Switch Tests(Envir.)

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Electrical Power					
Fuel Cell Assembly	CN	Pratt & Whitney	P&WA Preliminary Test Plan Rec'd. & Reviewed	DF-IP	Revised Reliability Input Being Incorporated into Amendment to P.O. Review of Preliminary Test Plan for Power Gen.Section (PGS) Development & Qualification Tests at GAEC Completed.
Cryo. H_2 & O_2 Storage & Supply Subsection					
Tank Assemblies	CV	AiResearch	NS	NS	Revised Reliability Input Incorporated in Amendment to Spec. & VR.
Check Valve	UP	-	NS	NS	
Solenoid Valve	UP	-	NS	NS	
Relief Valve	UP	-	NS	NS	
Quick Disconnect	UP	-	NS	NS	
Fill & Vent Valves	UP	-	NS	NS	
Battery	CB	Yardney	NS	NS	
Battery Charger	C	-	NS	NS	
Inverter	UP	-	NS	NS	Revised Reliability Input being Incorporated in Spec & VR

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Environmental Control					Preliminary Test Plan for ECS Development & Qualification Tests at GAEC Under Preparation.
Assembly & Components	CN	Hamilton Standard	HSD Preliminary Test Plan Rec'd & Reviewed	DF-IP	Revised Reliability Input Incorporated in Amendment to P.O. being Prepared.
Cold Plate Section	NA	NA	DF	IP	
Supercritical O_2 Storage & Supply	-	-	-	-	Grumman's EPS Group is Responsible for the O_2 Storage & Supply. See Elec. Power
CO_2 Sensor	UP	-	NS	NS	

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Instrumentation					
PCM/TE	CN	Radiation, Inc.	NS	NS	Timing Equipment Section to be Subcontracted to One Vendor-Common Usage
DSE	UP	-	NS	NS	Waiting MSC Direction
Sensors	UP	-	NS	NS	
Navigation & Guidance					
Rendezvous Radar	CN	RCA	UP	NS	
Transponder	CN	RCA	UP	NS	
Landing Radar	CV	Vendor to RCA	NS	NS	
Propulsion					
Ascent Engine	CN	BELL	Test Program Plan being Revised.	DF-IP	Firings Employing Early Injector Design Continuing Max. Single Test Time to Date 380 Sec.

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Propulsion (continued)					
Ascent Engine Component					Awaiting Bidder Proposal.
Pressurization					
Press, Reduc. Valve	C	-	NS	NS	LSP-270-715
Sol. Latch. Valve	C	-	NS	NS	LSP-270-713
Quad. Check Valve	C	-	NS	NS	LSP-270-716
Coupl., He Fill Disct.	C	-	NS	NS	LSP-270-812
Coupl., Test Point Disconnect	C	-	NS	NS	LSP-270-813
Helium Tank	C	-	NS	NS	LSP-270-711
Helium Filter	C	-	NS	NS	LSP-270-712
Pres. Relief & Burst Disc	C	-	NS	NS	LSP-270-717
Expl. Oper. Va. 3/8"	C	-	NS	NS	LSP-270-714
Expl. Oper. Va. ½"	C	-	NS	NS	LSP-270-819
High Press. Ck. Va.	C	-	NS	NS	LSP-270-718
Feed					
Coupling (Fuel)	C	-	NS	NS	LSP-270-701
Coupling (Oxidizer)	C	-	NS	NS	LSP-270-702
Burst Disc	C	-	NS	NS	LSP-270-703
Coupling 3/8"	C	-	NS	NS	LSP-270-804
Coupling ½"	C	-	NS	NS	LSP-270-805

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Propulsion (continued)					
Descent Engine					
Fixed Injector (Helium Injection)	CN	Rocketdyne	Test Program Plan Approved	DF-IP	Injector and Ablative Chamber Feasibility Tests continuing. First Workhorse Engine Test in Preparation. Max. Single Test 385 secs.
Variable Injector (Mechanically Throttleable)	CN	STL	Test Program Plan to be Revised.	DF-IP	Ablative Material Tests Completed. Injector Evaluation Tests Continuing.
Descent Engine Component					Awaiting Bidder Proposal
Pressurization					
He. Press. Tanks	C	-	NS	NS	LSP-270-811
He.Filter	C	-	NS	NS	LSP-270-814
Coupl. He Fill & Disct	C	-	NS	NS	LSP-270-812
Coupl. Test Point Disconnect	C	-	NS	NS	LSP-270-813
Latch. Sol. Va.	C	-	NS	NS	LSP-270-815

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Subcontractor (or Selected for) Negotiations	Test Plans	Tests	Remarks
Propulsion (continued)					
Descent Engine Component (continued)					
Pressurization (continued)					
Press. Reducer Va.	C	-	NS	NS	LSP-270-816
Quad. Ck. Valve	C	-	NS	NS	LSP-270-817
Pres. Relief & Burst Disc	C	-	NS	NS	LSP-270-818
Expl. Oper. Va. ½"	C	-	NS	NS	LSP-270-819
Feed					
Coupling (Fuel)	C	-	NS	NS	LSP-270-802
Coupling(Oxidizer)	C	-	NS	NS	LSP-270-803
Coupling Fill & Vent 3/8"	C	-	NS	NS	LSP-270-804
Coupling Fill & Vent ½"	C	-	NS	NS	LSP-270-805
Burst Disc. 2"	C	-	NS	NS	LSP-270-806
Filter (Fuel)	C	-	NS	NS	LSP-270-807
Filter (Oxidizer)	C	-	NS	NS	LSP-270-808

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Status of Test Program: Subcontractor (or Selected for) Negotiations	Status of Test Program: Test Plans	Status of Test Program: Tests	Remarks
Reaction Control					
Propellant Feed & TCA	CN	Marquardt	UP	IP	Preliminary Firing of 2 S/M Engines on Workhorse Cluster in Progress.
Propellant Tanks	CV	BELL	NS	NS	
He System Comp.	UP	-	UP	NS	
Stabilization & Control					
Guidance Coupler	UP	-	NS	NS	
Att. & Trans. Cont.	UP	-	NS	NS	
Rate Gyro	CB	-	NS	NS	
In-Flight Monitor	UP	-	NS	NS	
Att. Reference	UP	-	NS	NS	
Computer	UP	-	NS	NS	
Back-Up Programmer	UP	-	NS	NS	

TABLE 5-1 (continued)

Test Program Progress

Subsystem or Equipment	Status of Test Program: Procurement Document Status	Status of Test Program: Subcontractor (or Selected for) Negotiations	Status of Test Program: Test Plans	Status of Test Program: Tests	Remarks
Vehicle Design & Integration					
Ascent Engine Tanks	NA	NA	C	IP	Welding Technique Evaluation Test Plan Completed and Test in Progress. Slosh Test Plan and Test Completed.
Landing Gear Devel. Test	NA	NA	C	IP	
Windows	NA	NA	C	IP	

5.2 SUB-SYSTEM PROGRAM PROGRESS

5.2.1 Descent Propulsion

5.2.1.1 Rocketdyne (Helium Injection Throttling)

The Program Plan, which includes the Test Plan, has been accepted by GAEC. Some additional clarification was requested of Rocketdyne, but clarification was not sufficient reason to warrant another revision. The Reliability Plan still contained a paragraph implying component life test to failure. Rocketdyne was advised that the emphasis must be on over stress tests to failure. The only exception to this, it was pointed out, will be thrust chamber testing where life (duty cycle) testing to failure will be required.

The latest Monthly Progress report from Rocketdyne indicates that the test program is progressing well. A total of 30 tests on workhorse thrust chamber/injector assemblies have been run for a total of 1094 seconds. Eleven workhorse engine tests have been run for a total of 656 seconds. Three injector designs have been tested, two of a quadruplet hole pattern, and one of a doublet pattern. Approximately five other designs will be investigated. Throttling tests through a chamber pressure range from 146 psia down to 7 psig have been accomplished. A brief summary of recent tests is shown in Table 5.2.

TABLE 5.2

Summary of Recent Tests

Test No.	Date	Duration (secs) Plan	Actual	Pc *	Final	Remarks
020A	11-6-63	30.0	29.60	148.7	1.65	Test Satisfactory.
021A	11-7-63	250.0	244.80	150.5	1.65	Test Satisfactory.
022A	11-8-63	600.0	385.0	146.1	1.51	Facility Malfunction. Test Terminated.
023A	11-9-63		11.2	-	-	Instrumentation Malfunction. No Digital Data
024A	11-9-63		72.9	134.5	1.38	Facility Malfunction. Test Terminated.
025A	11-12-63	4.0	3.83	142.3	1.64	Bomb Test. Recovery Satisfactory.

* Last Recorded

5.2.1.1 Rocketdyne (Helium Injection Throttling)(continued)

A Bi-Monthly meeting was held on October 15, 16 and 17, 1963 at GAEC. Reliability Assurance tests and the overall test plan were reviewed. An amendment to the engine Design Control Specification is being prepared which will delete the Weibull analysis requirement and the numerical reliability requirement associated with it. In addition to this, a Reliability Boundary table of test parameters for all Reliability tests is being prepared.

5.2.1.2 Space Technology Labs (Mechanically Throttleable Engine)

The test program at STL is in the feasibility stage of the development program. Considerable testing has been conducted to finalize an injector design and to select the best material for the thrust chamber. Tests on subscale throat samples are essentially completed. A total of 90 inserts have been tested in tests totaling over 8,000 seconds. Evaluation of these results is presently in progress. Approximately 790 seconds of test time has been accumulated in 10.5K injector evaluation tests. The primary objective in this series of tests is to optimize the slot configuration for high performance. Initial testing on the flow control valve has started. Some vibration of the pintle has been experienced and this potential design problem is being investigated.

A bi-monthly meeting was held with STL on November 4 thru 7, 1963. During the latter two days a critique of the method in which test data will be analyzed was held. This meeting assumed added importance since the decision to delete the Weibull analysis requirement from the specification.

After considerable discussion it was decided that it would be less risky to treat only observed data without estimating or extrapolation, and to let the test engineer make his own extrapolation. The techniques presented to NASA on 10 September 1963 to analyze the test data were proposed. These techniques, in brief are:

1. Utilize non-parametric statistics to plot an upper 85% confidence point for the probability of failure at each stress at which a failure occurs.
2. Plot the failures on a graph of cumulative percent of a sample failing vs. increasing stress level.

Engineering judgment will dictate the extrapolation of the observed data as well as the interpretation of the proximity of the failures to the reliability boundary and the variance observed in the sample.

5.2.1.2 Space Technology Labs (Mechanically Throttleable Engine) (continued)

Work on the amendment to the Design Control Specification and Purchase Order is continuing. This amendment will include the deletion of the Weibull analysis and its associated numerical reliability requirement. In addition to this, a Reliability Boundary table for the various engine component tests and for the engine tests is being prepared as part of the amendment.

5.2.2 Ascent Propulsion

5.2.2.1 Bell Aerosystems Company

The Bell Program Plan including the Test Plan, has not been found acceptable by GAEC. The test plan was too general and did not clearly define the hardware being used in each test. In particular, the component hardware being utilized to meet the Reliability Assurance requirements was not designated. Comments were sent to Bell covering these objections and a revised Plan is being prepared.

Early feasibility testing is well on its way at Bell. A brief summary of latest test results is shown in Table 5.3.

TABLE 5.3

Test No.	Date	Duration (secs) Plan	Duration (secs) Actual	P c Final	O/F Final	Remarks Injector*
355	11-18-63	10	9.4	-	-	LT-2
356	11-26-63	10	9.9	121.7	1.56	LT-2
357	11-26-63	60	59.0	121.3	1.58	LT-2
358	11-26-63	380	380.6	105.6	1.57	LT-2

* Injector LT-2 is a modified Bell Injector used for early Injector and Thrust Chamber Feasibility Tests and is of a circular pattern design.

Tests are being run with LT (Bell early development model) series injectors and ablative chambers initially being received from three vendors. These injectors will be followed by A, B and C design injectors specifically designed for the LEM engine. The thrust chamber evaluation program will result in a final vendor selection for the LEM ablative chamber.

5.2.2.1 Bell Aerosystems Company (continued)

Some delays in the test schedule due to hardware manufacturing problems have been encountered. The manufacturing of the injector was particularly troublesome. Most of these problems have been overcome and the test program is beginning to move along on schedule again.

On 12 and 13 November 1963 a Bi-Monthly meeting with Bell was held at GAEC. The Reliability Test Program was briefly discussed. Bell will shortly submit a Reliability Test Plan which should cover all Grumman requirements.

GAEC is presently preparing an amendment to the Engine Specification which will delete the Weibull Analysis requirement as well as the numerical reliability requirement associated with it. In addition to this, a table is being prepared which defines the Reliability Boundary test parameters for all Reliability tests.

5.2.2.2 Propellant Feed & Pressurization Systems

All specifications and Vendor Requirements are completed. Vendors have been requested to quote and their proposals are being awaited. A list of Specifications prepared is shown in Table 5.1.

5.2.3 Reaction Control Subsystem - Marquardt

During the last quarter the contract with The Marquardt Corporation was signed. The first TMC Test Plan MTP-0014 was received and reviewed. Primary objectives of the tests outlined were "to demonstrate the capability of simultaneously firing (pulsing and steady state) two engines from a common propellant source, "and" to evaluate Cell 9 facility capabilities." The workhorse cluster configuration includes one mount assembly and two S/M engines using stainless steel altitude thrust chambers with flush-mounted chamber Pc tap. Testing is in progress and some preliminary data has been received by the subsystem group and is being evaluated.

Marquardt has completed the cost estimate for additional testing of common usage items and has submitted the estimate in a formal proposal. This proposal (TMC No. 2494) was received at the end of this reporting period and the evaluation has not been completed. The results of the evaluation will be completed during the next reporting period.

5.2.3.1 Propellant Tankage - Bell

The technical proposal from Bell was received and negotiations are in progress. The test program proposed by Bell makes maximum use of the design verification tests to incorporate stress-to-failure tests. A summary of the hardware to be used in the test program is given in Table 5.4.

TABLE 5.4

Propellant Tankage - Hardware Utilization

Prototype

(a) 1 Fuel Tank + Bladder Assembly
(b) 1 Ox Tank + Bladder Assembly

Design Verification

(a) 4 Fuel Tanks + 4 Bladder Assembly
(b) 4 Ox Tanks + 4 Bladder Assembly
(c) 4 Spare Bladder Assembly

5.2.3.2 Helium Pressurization Components

Procurement documents for the components of the helium pressurization system are still in various stages of preparation. The procurement documents for the helium tank and the ascent interconnect valve have gone through the engineering review stage and are awaiting final signatures before being sent to prospective vendors for proposals.

5.2.4 Stabilization and Control Subsystem

During the last quarter advances have occurred mainly in the procurement document area. Listed below is a summary of the individual assemblies.

5.2.4.1 Control Electronics Section

5.2.4.1.1 Rate Gyro Assembly

The proposals from three vendors, Kearfott, Minneapolis-Honeywell, and Nortronics were reviewed for the Reliability Assurance requirements and the results incorporated in the LEM Reliability vendor evaluation. This evaluation was submitted to the S & C subsystem engineering group responsible for the final evaluation and selection.

5.2.4.1.2 Gimbal Drive Assembly

Preliminary review of the Gimbal Drive Assembly design specification was completed and the updated Reliability Input and Reliability Boundary tables were submitted for inclusion in the Specification.

5.2.4.1.3 Preparation of the procurement documents for the Attitude and Translation Control Assembly (ATCA), Descent Engine Control Assembly (DECA) and Guidance Coupler Assembly (GCA) are in the preliminary stages and have not yet been released for Engineering Review.

5.2.4.2 Backup Guidance Section

5.2.4.2.1 Attitude Reference Assembly

Procurement documents for the Attitude Reference Assembly (ARA) were completed and signed off during this quarter but release to vendors has been delayed pending NASA approval of the documents.

5.2.4.2.2 Procurement documents for the Computer and the Programmer are in the preliminary stages of preparation and have not been released for Engineering Review.

5.2.5 Environmental Control Subsystem (ECS)

5.2.5.1 ECS Assemblies & Components - Hamilton Standard (HSD)

An amendment to the purchase order with HSD is under preparation incorporating the revised reliability assurance requirements as described in LPR-550-3, Quarterly Reliability Status Report, 1 November 1963. This revision will be completed following preparation of the applicable Reliability Boundary Table for the mission simulation.

5.2.5.1 ECS Assemblies & Components-Hamilton Standard (HSD)(continued)

HSD's Reliability Program Plan was received and reviewed for compliance with the purchase order and the design specification, LSP-330-2A. The test portion of the plan contained a number of discrepencies with respect to utilization of hardware, selection of environments and operating requirements of the equipment during the tests (e.g., working fluids to be used and operation requirements under 100 per cent oxygen atmosphere.) The detailed evaluation is contained in LMO-550-176. Pending correction of the errors and oversights, approval of the plan was withheld.

As of 1 December 1963, HSD has conducted feasibility tests in a number of areas including manufacturing processes, material compatibility and initial water boiler conceptual studies. In the latter studies, the performance of both the plate-fin and the porous plate boilers have proven unsatisfactory. Further boiler design studies and tests are scheduled.

5.2.5.2 Internal Environment Simulator (IES)

Additional reliability information on Hamilton Standard supplied equipment, as well as on the Environmental Control Subsystem itself, will be forthcoming from the IES test program. Following satisfactory completion of normal manned and unmanned operation checkout, the ECS equipment will be subjected to off-design and malfunction tests. The resulting performance data will be correlated with the data obtained from tests on lower levels of assemblies at the vendor and at GAEO for incorporation in the ECS reliability evaluation efforts.

5.2.5.3 Partial Pressure Carbon Dioxide Sensor

Preparation of the reliability assurance requirements, including the applicable reliability boundary conditions was completed for the CO_2 Sensor Detail Specification, LSP-330-202. The specification will be released shortly with Request for Proposals. These devices will be subjected to a simplified but relatively severe mission simulation prior to the stress-to-failure tests.

5.2.6 Electrical Power Subsystem (EPS)

5.2.6.1 Fuel Cell Assembly (FCA)-Pratt & Whitney Aircraft (PWA)

An amendment to the purchase order with PWA has been prepared incorporating the revised Reliability Assurance requirements in accordance with the boiler plate described in LPR-550-3, 1 November 1963. The amendment is presently being reviewed.

5.2.6.1 Fuel Cell Assembly (FCA)-Pratt & Whitney Aircraft (PWA) (continued)

Approval of PWA's Reliability Plan, which was received in October, was not granted. The areas of the plan primarily responsible for this rejection were the utilization of test hardware and the proposed mission simulation phase of the Reliability Assurance Tests. The detailed evaluation of the plan is contained in LMO-550-158. PWA was subsequently directed to revise their Reliability Plan incorporating the changes specified by LEM Reliability.

PWA initiated feasibility tests on a number of components during this quarter. The tests are summarized in Table 5.5.

5.2.6.2 Cryogenic Hydrogen & Oxygen Storage & Supply Tank Assemblies

The proposals received from six (6) companies for the development and manufacture of LEM EPS cryogenic tank assemblies were evaluated, the results of which are contained in LMO-550-153.

Upon selection of AiResearch for negotiations, attention was focused on clarifying three areas in the AiResearch proposal which concerned Reliability Test. They were: (1) insufficient information concerning the mission simulation; (2) the somewhat vague and misleading treatment of the stress-to-failure tests; and (3) the employment of only 2 of each tank assembly for the reliability assurance test phase of the development tests. These questions are being reviewed in the negotiations presently underway.

An amendment incorporating the revised Reliability Assurance requirements, to the cryogenic tank assemblies detail specification and vendor requirements document has been prepared and released to AiResearch. This amended detail specification and vendor requirements document will be the basis for the final contract negotiation.

5.2.6.3 Emergency Battery

Proposals received for the LEM back-up batteries were received and the evaluation reported in LMO-550-134.

The revised Reliability Assurance requirements were prepared for incorporation in an amendment to the detail specification and vendor requirements document and is to be released to Yardney Electric Corporation, the vendor selected for negotiations.

5.2.6.4 Status of other Procurement Documents

An amendment incorporating the revised Reliability Assurance

5.2.6.4 Status of other Procurement Documents (continued)

requirements, to the Battery Charger Detail Specification and Vendor Requirements was prepared and released to prospective vendors.

Detail specifications and vendor requirements are in the process of preparation for the following reactant supply components:

(1) Check valve

(2) Solenoid shut-off valve

(3) Relief valve

(4) Interstage disconnect

(5) Fill and vent valve

In addition, the General Purpose Inverter Detail Specification and Vendor Requirement is under preparation.

TABLE 5.5

Subcontractor Testing Fuel Cell Assembly

Pratt & Whitney Aircraft

Item	Test	Results
Reactant Control Subassembly		
Simulated fuel flow control value and seat	Calibration, using dry nitrogen and hydrogen-water vapor mixtures	No problems to date
Miniature switch (similar to that used in the fuel flow control for heater actuation and over-temperature signal).	Accelerated endurance test (cycling) under high temperature conditions.	Vailure after 4600 cycles (55 hours) including 600 cycles at 575°F. (See Table 5.6)
Reactor Subassembly		
Teflon seals and thoria insulator	Two seal test rigs assembled and run under 60 psia chamber pressure and 500°F.	Both rigs sealed KOH successfully. However, both seals experienced shorts. (See Table 5.6.) One test rig rebuilt with a teflon insulator replacing the ceramic insulator. Good performance to date.
Intercell heater	Tests for endurance, heating properties, plate insulation properties, dielectric strength and external resistance.	Satisfactory
Sealed Cells	Filling techniques	Techniques appear to be practical.

TABLE 5.6

LEM Fuel Cell Assembly Failure Summary

Report Period Ending 15 November 1963

Component	Part Number	Test Description	Failure Description	Corrective Action
Teflon Seal	AKP-4	Test Rig 27001-1 endurance test of the teflon seal from the single cell using the test rig assembly drawing AKP-8. Test conditions simulated actual cell running. KOH temperature 500°F, 84% KOH, 1.0 volt potential, 2000 psi seal load, and 60 psi chamber pressure. Failure occurred after 132 hours of testing.	Symptoms: Slight short was noticed after 65 hours of test, 100 milliamps was indicated across seal. The current gradually increased to 500 milliamps after 132 hours of test. Analysis: Metallic deposit across insulator caused the electrical short	Development testing is continuing for further definition of problem characteristics.
Switch (Same as that to be used in H_2 Flow Control)	Microswitch 6HMI	Cycled switch 2 cps with spring load of 4.5 pounds Test started with switch in over at 475°F. Every 1000 cycles the over temperature was raised 25°F.	Switch contacts welded in closed position after 4600 cycles. Oven temperature was at 575°F at time of failure	Switch sent to manufacturer for analysis

SOURCE: PWA-2414, 10 December 1963

5.2.7 Instrumentation

5.2.7.1 Pulse Code Modulation & Timing Equipment (PCMTE)

Final negotiations with Radiation Inc. were concluded during this period and the purchase order was released.

The outcome of the analysis of the trade-offs between assembly level and equipment level stress-to-failure testing resulted in a decision in favor of equipment level testing. It is felt that this decision is well founded since a high degree of commonality with the command module PCM does exist and good historical test data is available for the components and assemblies.

The proposed vendor test schedule is presented in Table 5.7. It should be noted that design verification tests are being fully implemented via the two prototype equipments alloted for Reliability Assurance Tests.

5.2.7.2 Data Storage Equipment (DSE)

During this quarter GAEC was directed by MSC, reference TWX SLE-10-597-63-193 to GAEC dated October 29, 1963, to stop all effort on the DSE until MSC had completed its own review of the data storage requirements.

At this time GAEC is waiting further direction.

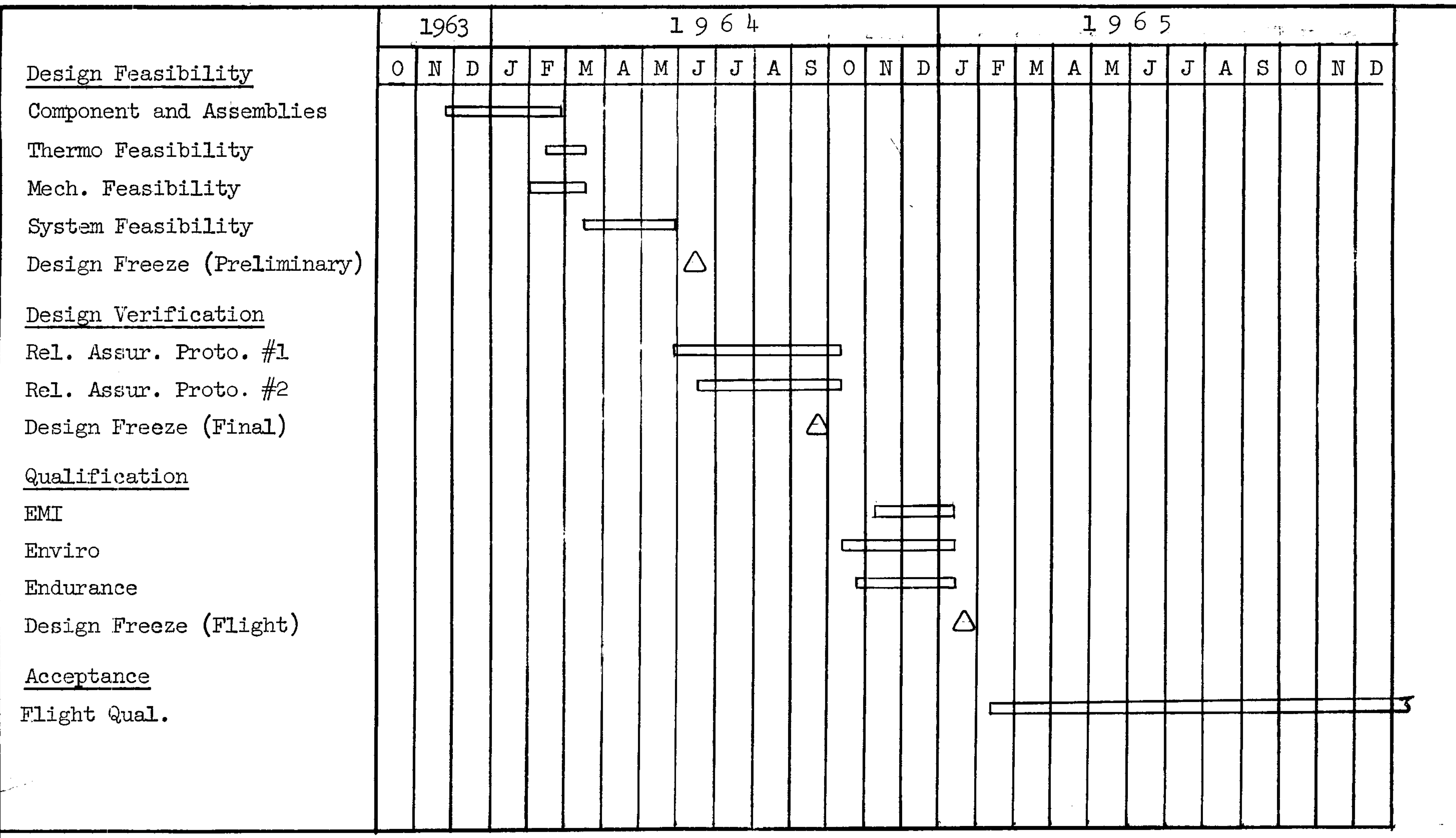


TABLE 5.7

PCM/TE Test Schedule

5.2.8 Communication Subsystem

Vendor negotiations with RCA relative to the Reliability Assurance Test Program are in progress. RCA has been informed of the deletion of the Weibull Analysis requirement. As a replacement for this Weibull constraint, Grumman has imposed a no failure in test criteria for the purpose of instituting a more stringent requirement on the design and manufacture of Development type hardware. Implementation of this requirement is to be accomplished in the Mission Simulation and check of Qualification Test Phases of the Reliability Assurance Test Program.

The RCA Proposed Test Program is presently undergoing considerable scrutiny relative to the integration of the various assemblies into a projected packaging configuration. The investigation is also to determine to what extent the test requirements will be imposed on each assembly to achieve maximum test effectiveness. Under evaluation is RCA's proposed integrated, three electronic assembly unit, which is called an LRP (LEM Replaceable Package). The LRP involves the following two sets of assemblies: S-Band Diplexer, S-Band Transceiver and S-Band Power Amplifier; and a VHF Transceiver, Premodulation Processor and Audio Center. Projected test problems associated with this proposed integrated electronic package should be minimized because of the tests being conducted under actual rather than simulated operating conditions, i.e., with respect to hardware-materials and components-and environments such as temperature.

As part of the Mission Simulation requirement in the Reliability Assurance Test Program, Grumman has instituted an Integration and checkout test to measure the capability of the equipment to perform extended periods of time without any marked degree of degradation in performance of the equipment, i.e., deviating beyond the limits stated in the specification. This test, imposed on each communication electronic assembly unit, will require a 500 hour period of operation (under ambient conditions) to insure that the equipment shipped from each vendor will not exhibit any serious falloff characteristic or go beyond minimum acceptable performance for the integration and checkout phase of the Grumman LTA or LEM programs.

The proposed Vendor (RCA) Test Schedule for the Communication Subsystem is shown in Table 5.8 indicating significant starting and termination dates. In Fig. 5.1, which was presented in the last Quarterly Report, one change has transpired and that is the removal of the Portable Television Camera from a Grumman subtracted item to one to be delivered as GFE (reference TWX SES-12-189/T701/630160 from MSC).

DESIGN FEASIBILITY

Dev. of B B Assemblies
Antenna Pattern Test
Section Integration (Bench)
Dev. of Exp. Model *
LRA Integration **
Dev. of Service Test Model *
Preliminary Design Freeze

DESIGN VERIFICATION

Reliability Assurance
  Electronic Assemblies
  Antenna Assemblies
Section Integration
Development Models *
Subsystem Integration
Final Design Freeze

QUALIFICATION

Environmental
Endurance

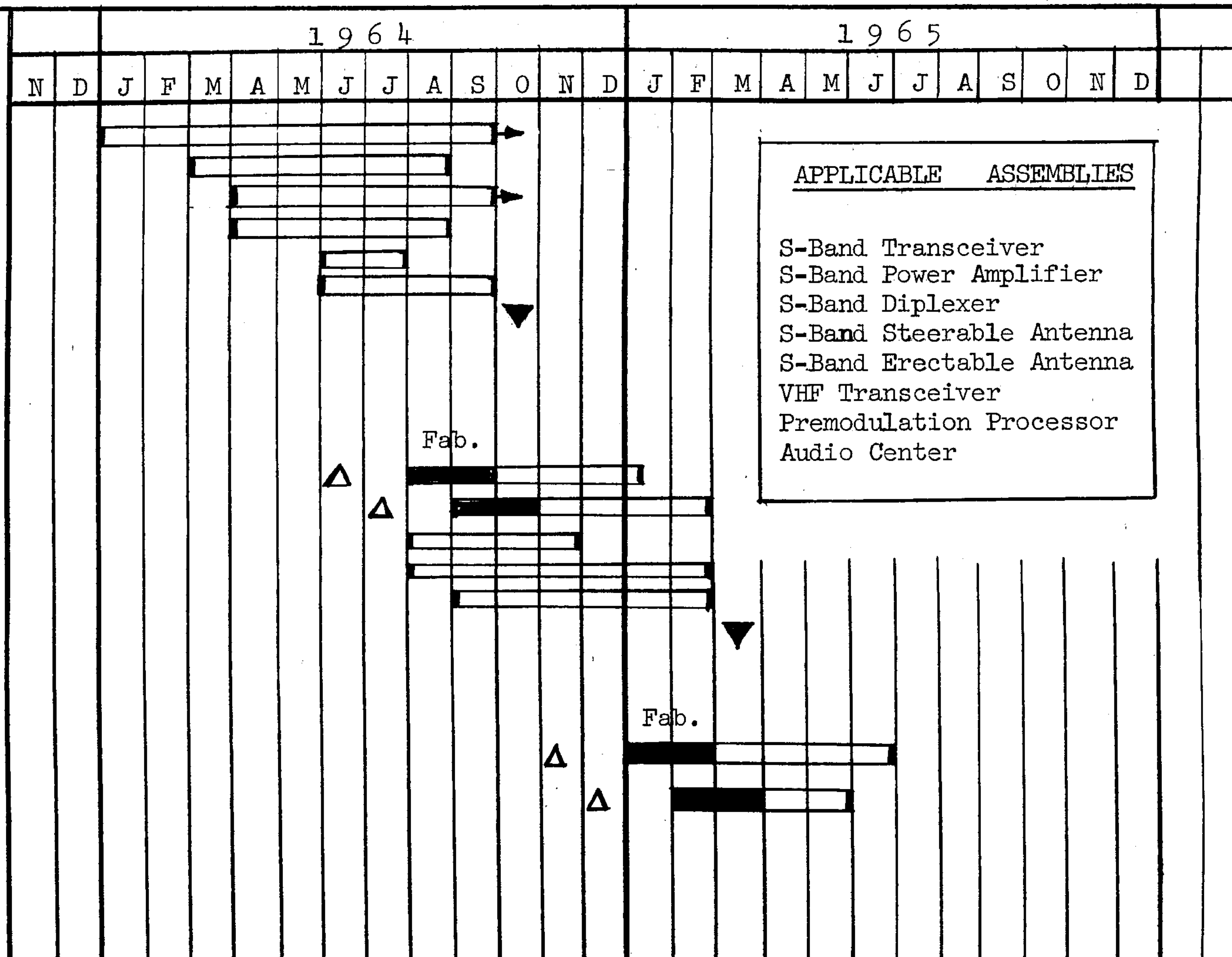


TABLE 5.8

VENDOR TEST SCHEDULE

COMMUNICATIONS (RCA)

LEGEND: △ Detail Test Plan Submittal Data
▼ Design Freeze
* Includes Fabrication
** Proposed by RCA

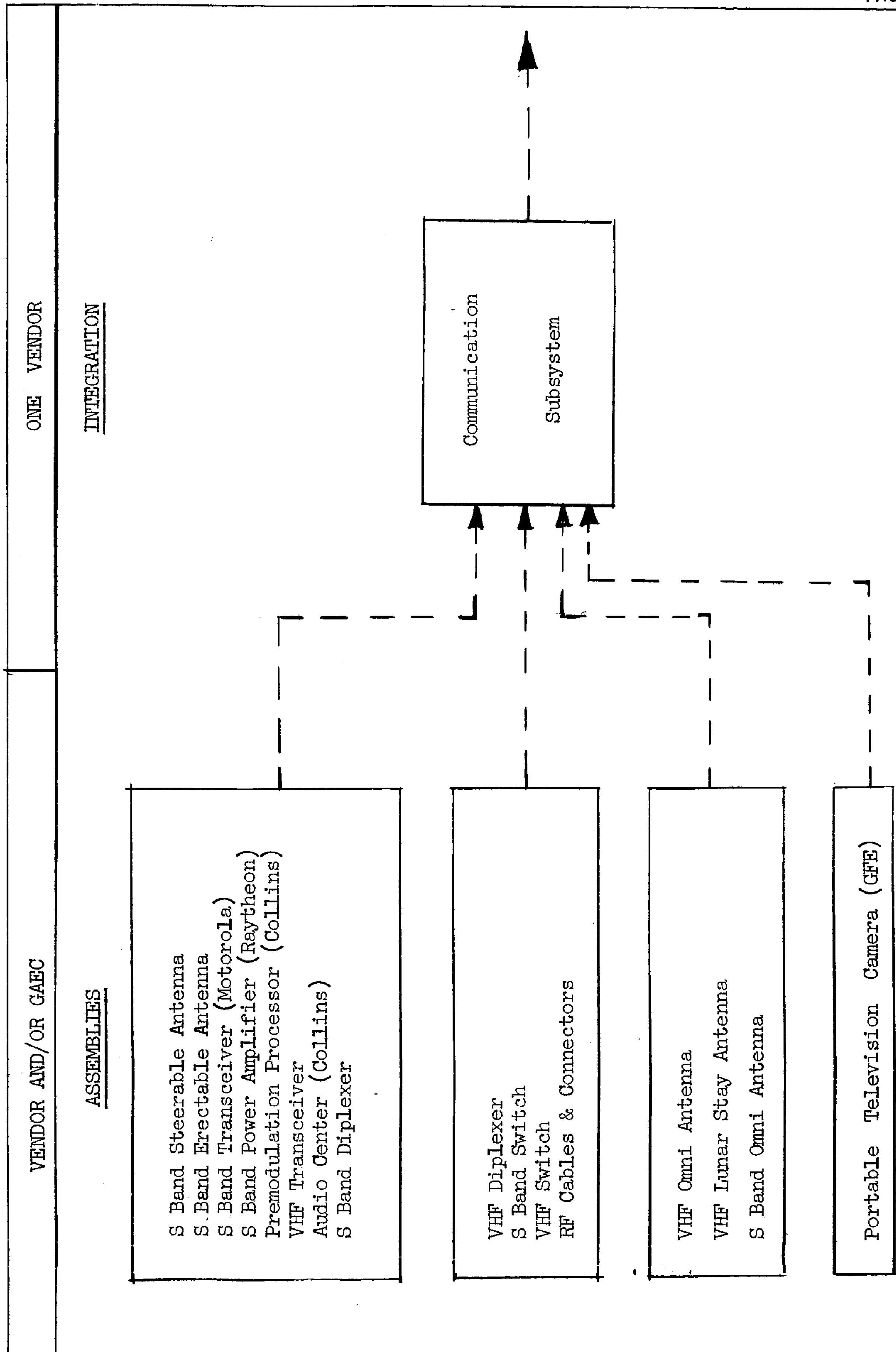


FIGURE 5.1
Procurement Grouping of Assemblies

5.2.9 Radar

As of November 13, 1963 RCA has been under contract with Grumman and is expected to comply with the requirements stated in Purchase Order 2-18846-c. Reliability Control is aware that certain technical problems concerned with the Radar such as Antenna Plume effects (engine firing affecting the intensity and distribution of the radiation pattern), transmitter frequency of the Landing Radar and interface requirements have not been resolved to date but are in the process of continued and urgent evaluation. With respect to the frequency of the LR, this decision has not been reached pending a final award of the LR subcontract from RCA.

The projected test program for the Radar equipment at Grumman, as briefly mentioned in the previous Quarterly Report, is to subject the subassemblies and assemblies to a critical as well as an independent test program. Test Bench facilities and associated procedures are being implemented at this time with test requirements to include maximum and minimum limits of excursions.

The intent of examining lower order of assembly equipments is to unmask marginal as well as poorly designed circuits and to uncover inferior quality hardware, including components which do not meet Grumman's standard of performance or workmenship. As a measure of meeting the performance requirements, the projected Grumman effort will be to probe each circuit for the correct signal and voltage or current characteristics and at the same time check the adequacy of the Vendors test point designs for each assembly or subassembly item. From the system point of view, Grumman is planning to conduct flight tests, as part of the Development Test Program, to measure proper system performance in the early stages of the Radar design.

The quantity of hardware for the Landing Radar Antenna and Electronic Assemblies, designated for the Reliability Assurance Test Program, has been changed from four to three units of each. The basis for this decrease in equipment requirement, is the placing of the LR in the category of Criticality Class II, which is defined as a Mission Success item in accordance with Grumman's Mathematic Model definition. The fact that the LR has a backup in the Rendezvous Radar Contributes to the LR status as a Class II Criticality.

5.2.10 Structures and Materials

The forth quarter period saw the LEM Structures and Materials program progress in several areas. The Descent Stage Propellant Tank Assembly Subcontract was awarded to Allison on 11 December 1963. In addition, various test programs were initiated, test plans were prepared and some feasibility Tests completed on structural components and material investigations.

5.2.10.1 Descent Stage Propellant Tank

The Descent Stage Propellant Tank Assembly Design Control Specification LSP-280-4, and Vendor Requirement LVR-280-4, 7 August 1963 were released for competitive bidding. Proposals were received from Aerojet, Airite, Allison, Beechcraft, Lycoming, and Manasco. After approximately 3 weeks of negotiations, Allison was awarded the contract on 11 December 1963.

5.2.10.1.1 Vendor Proposal Evaluation

The six vendor reliability programs were evaluated at GAEC. Of the six bidders, Aerojet advanced a program which most nearly answered in letter and intent, the specified Grumman Requirements.

5.2.10.2 Vendor Negotiations-Allison

The selected vendor for the Descent Stage Propellant Tank is Allison. During the negotiation phase the responsible reliability engineer assisted the Vehicle Design and Integration Group in, clarifying and delineating Allisons development and test program rationale. The GAEC statistical demonstration requirement (Weibull distribution) was deleted and the requirement of the "successful completion of the (reliability) tests shall be a prerequisite to the start of the formal Qualification Test" was substituted. This requirement generated the desired effect of forcing Allison to place greater emphasis into their Design Feasibility program. Table 5.9 indicates the extent and coverage which the Design Feasibility tests plays early in the test program. For example, item i.e., Table 5.9 are two propellant tank feasibility assemblies (Modified NAA Apollo tank assemblies) the successful testing of which will substantially assure that the Reliability and Qualification assemblies will meet their requirements further downstream. A summary of the hardware to be utilized in the program is given in Table 5.10 below

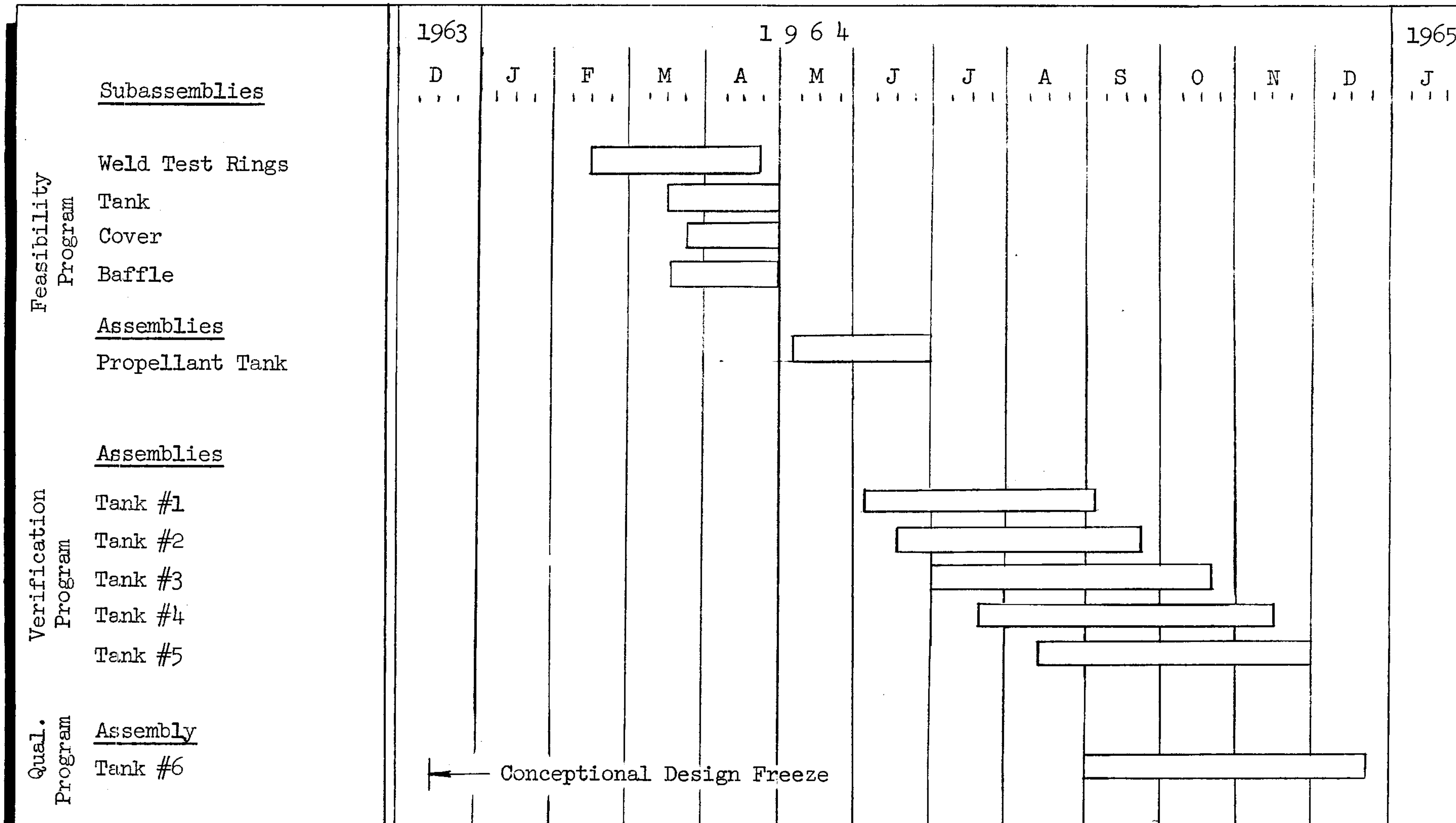


TABLE 5.9

Allison Test Program Schedule Descent Stage Propellant Tank Assembly

TABLE 5.10

Descent Stage Propellant Tank Assembly Hardware Utilization

I Feasibility Program

A. Eight (8) Weld Test Rings
B. Two (2) Tank Subassemblies
C. Three (3) Cover Subassemblies
D. Five (5) Baffle Subassemblies
E. Two (2) Propellant Tank Assemblies

II Verification Program

A. Four (4) Reliability Tank Assemblies
B. One (1) Design Verification Tank Assemblies

III Qualification Program

A. One (1) Tank Assembly

5.2.10.2 Ascent Stage Propellant Tanks

The reliability test requirements were incorporated into the Ascent Stage Propellant Tank specification. Specification is in the engineering review stage at the time of writing. The same successful Descent Stage Propellant Tank reliability assurance test requirements will be utilized in the Ascent Stage Propellant Tank Specification.

5.2.10.3 Materials

5.2.10.3.1 Various material feasibility investigations were conducted during this quarter. For a full listing of the test plans and reports that were reviewed by Reliability Control, refer to paragraph 5.2.1.1. Appendix III.

5.2.10.3.2 A weld investigation in which Reliability Control played a significant role so far as designing the experiment (reference LMO-550-64) was the "Ascent Tank 2014-T6 Weld Test Program". Briefly, the purpose of the investigation is to determine the effects, if any, of two variable on the weld strength of the Ascent Tanks. The two variables are:

A. Weld Filler Rod Material
A(+) 4043 filler rod
A(-) 2319 filler rod

5.2.10.3.2 (continued)

B. Weld Bead Condition
B(+) Weld Bead Ground
B(-) Weld Bead Unground

This variable is a final grinding fabrication process on the weld bead. The arguments are that grinding could eliminate sources of stress concentration and conversly, grinding could adversly affect the strength because of removal of the weld "beef".

The original plan proposed the classical approach of one-variable-at-a-time. Reliability Control redesigned the experimental plan utilizing the statistically designed full factorial design at two levels with four replications ($4x2^2$) The effects of the uncontrolable variables (operator factique, machine speed fluctuations, etc.) are reduced or eliminated by randomization of the fabrication process order. The plan is presented in a systematic array in Figure (A) and in Block form in Figure (B).

		A	
		A (-)	A (+)
B	B(-)	(1)	(a)
	B(+)	(b)	(ab)

FIGURE (A)

Treatments Combination	Factor A	Factor B	Effect AB
(1)	-	-	+
(a)	+	-	-
(b)	-	+	-
(ab)	+	+	+

FIGURE (B)

The postulated setup is as follows: the response in a trial with A at the i^{th} level and B at the j^{th} level for the k^{th} trial of this treatment is written as:

$$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + E_{ijk}$$

where: μ denotes the true mean
A_i is the true mean in which A is at the i^{th} level.
B_j is similarly defined
AB_{ij} measures the AB interaction
E_{ijk} measures the experimental error.

5.2.10.3.2 (continued)

The total factorial effect for A, B and the AB interaction is calculated using Figure B.

$$2A = \left(\left[(a) + (ab) \right] - \left[(1) + (b) \right] \right)$$

$$2B = \left(\left[(b) + (ab) \right] - \left[(1) + (a) \right] \right)$$

$$2AB = \left(\left[(1) + (ab) \right] - \left[(a) + (ab) \right] \right)$$

The significant factors are determined using the Analysis of Variance as presented in Table 5.11 in conjunction with the F-ratio table.

TABLE 5.11

Analysis of Variance Table to determine the Significant factor(s) from the Weld Test Program (para. 5.2.11.3.2)

(1) Source of Variation	(2) Factor Effect	(3) Sum of Squares	(4) Degree Freedom	(5) Mean Square
A B AB	A/2 B/2 AB/2	$(2A)^2/16$ $(2B)^2/16$ $(2AB)^2/16$	1 1 1	$(2A)^2/16$ $(2B)^2/16$ $(2AB)^2/16$
Sum		$SS = \frac{(2A)^2 + (2B)^2 + (2AB)^2}{16}$	3	
Error		$SS_E = SS_T - SS$	12	$\frac{SS_E}{12}$
Total		$SS_T = \sum_{i=1}^{16} (X_i)^2 - \frac{(X_T)^2}{16}$*	15	

* where X_i denotes the i^{th} observation

X_T denotes algebraic sum of all observations

5.2.11 Crew Provisions

During the forth quarter, the status of the Crew Provisions test program was primarily in the conceptional phase with test plans in vari ous stages of preparation.

5.2.11.1 Development Testing

Test plans are in preparation for the design feasibility testing of such items as display panels, instrumentation mounting clamps, etc. Maximum usage of the GAEC mission simulation and stress-to-failure techniques will be employed during these tests with Reliability Control actively participating in the formulation of the test plans. A listing of the Crew Provisions test plan are delineated in Appendix III, paragraph 5.1.1.

5.2.11.2 Reliability Testing

The reliability test program is in the definition stage. Test Schedules have been generated for the different sections (Table 5.12). In addition, a test hardware quantity list based on the criticality of the particular section has been prepared and is presented in Table 5.13. In all instances, Reliability Control will impose the same mission simulation and stress-to-failure, concepts and requirements, on GAEC in-house designed sections that are being imposed on the Vendor equipment. In addition techniques are being studied for the lighting section tests, to couple the statistically designed experiment (factorial designs) with the mission simulation tests. If the studies are fruitful, it is anticipated that it will increase the information yield per test and in addition provide definitive data on the effects of environments on lamps parameters.

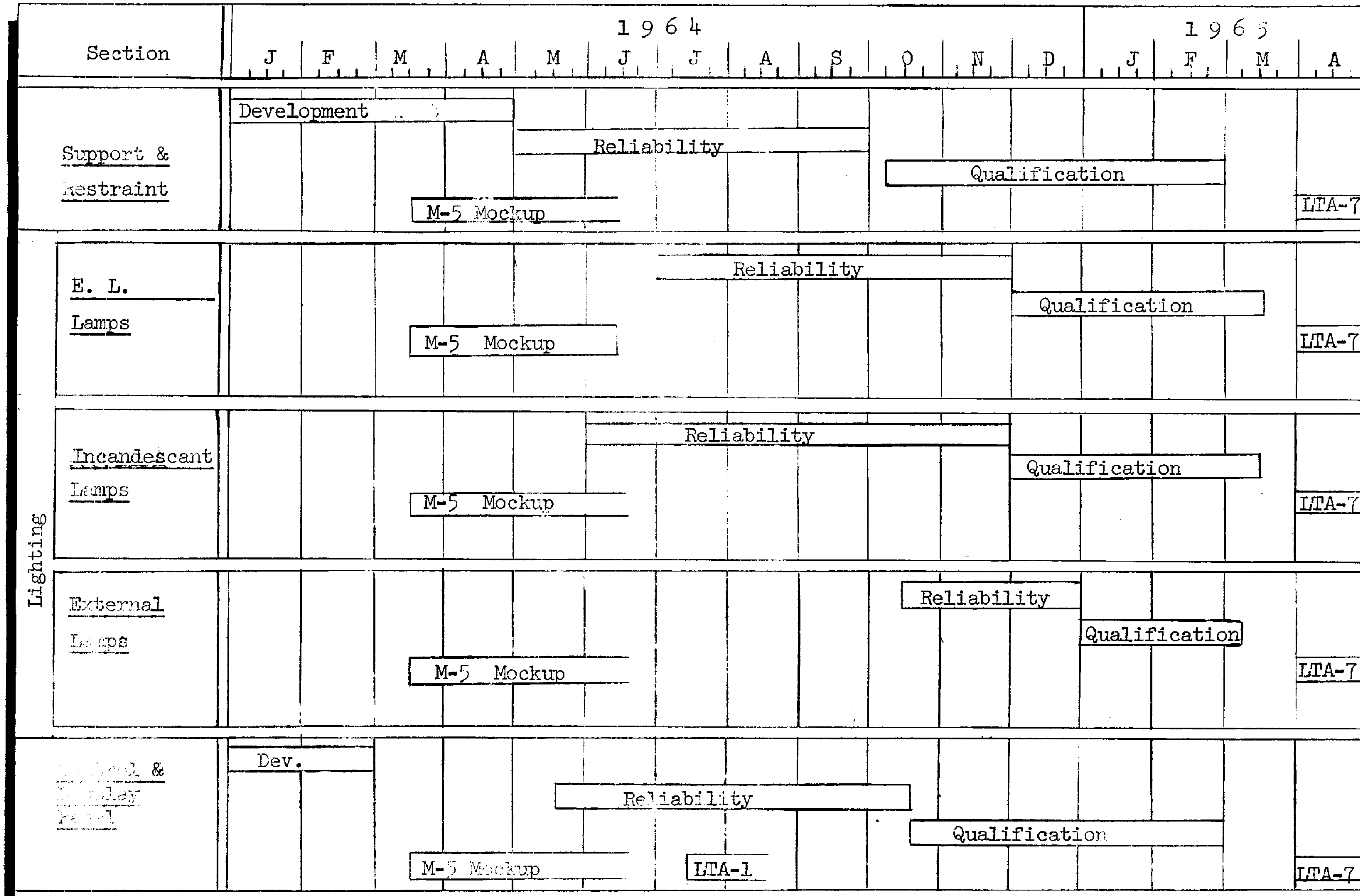


TABLE 5.12
LEM Crew Provisions Subsystem Test Program Schedule

TABLE 5.13

Reliability Test Hardware Utilization Crew Provisions Subsystem

Section	Criticality I	Criticality II	Criticality III	Hardware Quantity
Crew Support & Restraint		X		3
Crew Asc/Desc. Provisions			X	2
Control & Display Panel		X		3
Lighting		X		3
Waste Management		X		3
Water Dispensing Prov.		X		3
Crew Prov. Devices			X	2

5.2.12 Controls and Displays

Activities currently in progress center around the effort associated with incorporating the Reliability Test requirements and Reliability Boundary Table into the equipment Specifications and Vendor Requirement Documents listed in Table 5.14 below.

TABLE 5.14

	Equipment	LSP No
A	Gimbal Attitude Indicator	350-301
B	Gimbal Angle Sequence Transformation Assembly	350-302
C	Event Timer	350-304
D	Electronic Clock	350-601
E	D'Arsonial Meter	350-801

The electronic clock, LSP-350-601, dated 18 October 1963 was released for competitive bidding and Vendor proposals.

5.2.13 Ground Support Equipment

During the past quarter an effort was made to define a Reliability Test Program for GSE "Carry-on" equipment. A rough draft of the program plan was submitted for evaluation by the LEM Reliability Group. The evaluation has not yet been completed.

5.2.13 Ground Support Equipment (continued)

However, it should be noted that although no formal reliability program presently exists, all specification and procurement documents initiated on the LEM program are reviewed by Reliability. At a minimum the specifications and documents are reviewed for their compliance to the overall reliability objectives set for the LEM program. More specifically, owing to the broadness of scope of the equipment categorized under GSE, each specification and/or VR is evaluated on its own merits dependent on its intended use, e.g., special test equipment, development test equipment, simulators.

It is intended to continue this effort in this manner until such time as a formal plan is established.

5.3 SYSTEM TESTING

The System Test planning phase has progressed during this quarter on schedule. The LTA-2 and LTA-3 Test Plans were prepared in the preliminary form and released.

The LTA test program was approved by MSC. Table 5.15 reflects the approved test objectives and revised reliability objectives for each LTA vehicle.

The coordination between System Test and Reliability Control-Testing has been improved resulting in a better understanding of the testing and reliability requirements.

TABLE 5.15

LTA Test Plans

Test Article	System Test Objective	Reliability Objective
LTA - 1 House Spacecraft (Electronic Integration)	1. Establish that the LEM Subsystems are compatible and that no electrical or mechanical interface problems exist. 2. Evaluate the LEM Subsystems compatibility with the GSE and PACE checkout equipment. 3. Determine the adequacy of the Operational Test Procedures to support the LTA and LEM test programs. 4. Develop and test modifications resulting from the Ground and Flight Test programs.	1. Confirm the Reliability Failure Effect Analysis and Contingency Analysis. 2. Verify the Reliability Prediction Analysis, Component Test results and Failure Rate Assumptions. 3. Verify Subsystem and GSE Design Assumptions used in the Failure Mode Prediction. 4. Obtain failure data. 5. Determine the effects of the interaction between subsystems.
LTA - 2 Stability Demonstrator	1. Confirm Vehicle Stability under Critical Landing Conditions. 2. Evaluate Landing Gear Energy Absorbtion Characteristics. 3. Determine Strength Margins of Gear Structure. 4. Support Static Firings/Vibration Test of CIB and C5 at MSFC	1. Verify shock and vibration levels used for Reliability Boundary Level Tests and Stress-to-Failure tests and correlate K factors (Failure Acceleration Factors) assumed for Reliability Analyses.

TABLE 5.15 (continued)

LTA Test Plans

Test Article	System Test Objective	Reliability Objective
LTA - 3 Structural Test	1. Determine adequacy of LEM structure to sustain critical static laoding sustained during each mission phase. 2. Demonstrate structural strength margins under critical mission vibration environments using simulated subsystem. 3. Determine basic body modes of the LEM utilizing simulated subsystems. 4. Demonstrate adequacy of Electrical-Mechanical Separation Systems during LEM staging. 5. Determine the adequacy of the complete LEM structure to sustain the critical lunar landing loads. 6. Determine structural margins and failure modes to establish areas for potential weight reduction.	1. Verify shock and vibration levels used for Reliability Boundary Level Tests and Stress-to-Failure Tests. 2. Identify Magnification Factors and correlate with Reliability Analysis Assumptions. 3. Obtain failure data.
LTA - 4 Vibration and House Spacecraft	1. Evaluate the performance of the integrated LEM subsystems under critical mission vibration levels. 2. Demonstrate that LEM subsystems will function during and subsequent to the lunar landing impact.	1. Under Thermal-Vacuum Environment, Verify Subsystem Design/Operation Assumptions used in Failure Mode Prediction, Failure Rate, Reliability Boundary Conditions and Stress-to-Failure Analyses.

TABLE 5.15 (continued)

LTA Test Plans

Test Article	System Test Objective	Reliability Objective
LTA - 4 (continued) Vibration and House Spacecraft	3. Demonstrate Acceptance and Checkout Procedures to be used at the factory an deliverable LEM vehicles. 4. Determine the satisfactory performance of an integrated LEM System under vacuum and 100 percent oxygen environment.	2. Correlation of Over-Mission Off-Design and Degraded Subsystem Operation to the Reliability Analysis and Component Test Results. 3. Obtain failure data for Failure Rate and Failure Mode Analysis. 4. Verify shock and vibration levels used for Reliability Boundary Level and Stress-to-Failure Tests. 5. Determine the effects of the interactions between the subsystem aboard the LTA-4.
LTA - 5 Propulsion Demonstration and Test Article	1. Evaluate the performance of the LEM Propulsion Systems and RCS with flight weight structures to assure qualification for all flights. 2. Evaluate LEM Fire-in-Hole under simulated lunar launch and emergency abort conditions.	1. Verify Subsystem Design/Operation Assumptions used in Failure Mode Prediction, Failure Rate, Reliability Boundary & Stress-to-Failure Analyses. 2. Correlation of Over-Mission Off-Design and Degraded Subsystem Operation to the Reliability Analysis & Component Test Results

TABLE 5.15 (continued)

LTA Test Plans

Test Article	System Test Objective	Reliability Objective
LTA - 5 (continued) Propulsion Demonstration and Test Article	3. Evaluate the operation of the Propulsion System under the various mission phases integrated with SCS and EPS. 4. Evaluate the operation of Propulsion System under Off-Nominal Conditions and Redundant Modes. 5. Evaluate operational GSE and procedures to be used for handling and servicing hypergolic and cryogenic fluids at AMR.	3. Obtain failure data for Failure Rate and Failure Mode Analysis. 4. Verify vibration levels used for Reliability Boundary Level and Stress-to-Failure Tests. 5. Determine engine life under LTA-5 environment to verify Development Test data on engine and Components. 6. Determine the effects of Propulsion and RCS Subsystems interaction with the other subsystems aboard LTA-5.
LTA - 6 Apollo Integration	1. Evaluate electrical and mechanical compatibility of the CSM/LEM and Adapter under static and dynamic conditions. 2. Demonstrate and develop Crew Transfer Procedures for the two docked positions. 3. Evaluate compatibility of LEM/CSM under simulated flight vibrations (modal testing)	1. Analyze and evaluate any unexpected Dynamic interaction between LEM and the CM/SM thru interface and correlate with Reliability Analyses for reassessment if necessary. 2. Obtain failure data. 3. Verify shock & vibration levels used for Reliability Boundary Level Tests & Stress-to-Failure tests & correlate K factors (Failure Acceleration Factors) assumed for Reliability Analyses

TABLE 5.15 (continued)

LTA Test Plans

Test Article	System Test Objective	Reliability Objective
LTA - 7 Manned LEM Environmental Vehicle	1. Evaluate the capability of the LEM subsystems to operate unmanned during boost and earth orbit. 2. Evaluate the performance of the manned LEM under the thermal-vacuum environment of LEM excursions in earth orbit. 3. Evaluate the performance of the manned LEM under the thermal-vacuum environments of the lunar landing. 4. Demonstrate and develop procedures for operation on the lunar surface during the lunar stay.	1. Under thermal-vacuum environment verify Subsystem Design/Operation Assumptions used in Failure Mode Prediction, Failure Rate Reliability Boundary Conditions and Stress to-Failure Analysis. 2. Correlation of Over-Mission, Off-Design and degraded Operation to Reliability Analysis and Component Test Results. 3. Obtain failure data for Failure Rate and Failure Mode Prediction. 4. Verify vibration levels used for Reliability Boundary Level and Stress-to-Failure tests.
LTA - 8 Manned CSM/LEM Compatibility Vehicle	1. Evaluate the performance of the manned CSM/LEM under the thermal-vacuum environments of each Apollo mission phase. 2. Evaluate the performance of all Apollo systems after simulated missions to determine adequacy of the integrated CSM/LEM.	1. Under thermal-vacuum environment verify Subsystem Design/Operation Assumptions used in Failure Mode Prediction, Failure Rate, Reliability Boundary Conditions and Stress-to-Failure Analysis.

TABLE 5.15 (continued)

LTA Test Plans

Test Article	System Test Objective	Reliability Objective
LTA - 8 (continued) Manned CSM/LEM Compatibility Vehicle	3. Demonstrate and develop Integrated Checkout, Servicing and Countdown Procedures for the Apollo Spacecraft. 4. Demonstrate the EMI compatibility of the CSM/LEM configuration.	2. Correlation of Over-Mission, Off-Design and degraded Operation to Reliability Analysis and Component Test Results. 3. Obtain failure data for Failure Rate and Failure Mode Prediction. 4. Verify vibration levels used for Reliability Boundary Level and Stress-to-Failure tests.

5.4 FLIGHT DEVELOPMENT PROGRAM

Plans are being formulated to meet NASA Work Statement requirements through a coalition of engineering efforts on an omni-informed basis. Emphasis will be placed on the monitoring of all Flight Test Development plans to cover environmental and performance data to support the estimation of the numerical reliability of each subsystem.

During the quarterly reporting period Detailed Test Plan LEM-1 has been investigated along the lines of the aforementioned paragraph.

APPENDIX A

Generalized Reliability Test Input To Equipment Specifications

Working Format

4.4.2 Reliability Assurance - As an integral part of the development test program the ______________________________ * shall be subjected to a mission simulation test under the Reliability Boundary Conditions, a check of Qualification Test levels, and a stress-to-failure test. No failure shall be permitted during the mission simulation or check of Qualification phase. Successful completion of these tests shall be a prerequisite to the start of the formal Qualification Test. Tests applicable to reliability assurance shall fulfill the following essentials:

(a) The tests shall be conducted on equipment which is representative in design, physical configuration and material to deliverable flight weight equipment as approved in the Test Plan.

(b) The equipment shall be subjected to one mission simulation at the Reliability Boundary Conditions of Table_____. The mission simulation shall take into account the critical environments and dynamic conditions to which the equipment will be exposed during the acceptance tests, handling, transportation and storage, prelaunch, launch, translunar, and lunar phases of the LEM mission.

(c) At the completion of the mission simulation the specimen shall be subjected to the maximum conditions specified in Table II, Requirements for Qualification Tests, using the exposure time in Table _____. Equipment shall be operating or not operating as shown in Table II. Where practical, qualification test levels shall be approached gradually, or in discrete increments, in order to pin point stress levels in case a failure occurs prior to attaining qualification levels.

(d) At the completion of the mission simulation and check of qualification test levels, the equipment shall be tested to failure under systematically increasing dynamic and environmental stresses. Failure is described as deviation of performance from the minimum acceptable operating mode.

The Failure Mode Prediction Analysis shall provide the basis for the selection of critical stresses to be employed in the stress-to-failure tests. If critical stresses are due to a combination of environmental conditions, the tests shall be performed under that combination of environments. If critical stresses are due to a single environment which is encounted in combination with other environments during the

* The level of assembly for these tests will be specified.

4.4.2 Reliability Assurance (continued)

(d) continued

mission, tests shall be performed under that combination of environments. During these tests, the conditions shall be increased in proportion to their value at the Reliability Boundary.

Input parameters, such as mass flow, voltage, current, frequency, etc., shall be maintained at the value chosen for the Reliability Boundary so as to determine the effect of increased stresses on the output of the equipment.

Stress-to-failure tests on limited life items, or items for which operating time or cycles may be significant in producing lower failure modes, shall include with each increment an exposure time or number of cycles which is in proportion to the per cent stress increment and the exposure time of the simulated mission. All other equipment shall dwell long enough at each increment to stabilize conditions, and complete a performance test (abridged operational test) in order to check on performance degradation.

Where the Failure Mode Prediction Analysis has designated as critical several environmental and dynamic conditions which are not in combination in the mission, a uniform per cent overstress of each condition shall be imposed on the specimen prior to advancement to the next increment.

4.4.2.1 Analysis of Results - Vendor shall perform an engineering analysis of the data generated by the stress-to-failure tests including a correlation with the Failure Mode Prediction Analyses and submit the data and the analysis to Grumman.

RELIABILITY BOUNDARY CONDITIONS TABLE

General Requirements

(1) All conditions shall be imposed on equipment in the unpackaged state. (unless otherwise noted)

(2) Test Procedures shall be in accordance with Paragraph__________.

(3) The conditions specified in this table shall be simulated in the sequence shown. Any deviation from the requirements of this table shall be subject to the approval of Grumman.

(4) Unless otherwise specified, the equipment shall be operated in accordance with Paragraph__________ during the tests.

(5) Perform Operational Test as per Paragraph __________ before and after exposure to non operational test conditions.

(6) Unless otherwise specified, operating parameters, mass flow, internal pressure, voltage, current, etc., shall be maintained at their maximum or minimum tolerance levels, whichever is most wearing on the equipment.

(7) Prior to the vibration portion of the test, a resonant frequency search shall be conducted between 5 to 2000 cps with any resonant frequencies and the approximate amplification mode recorded. The vibration RMS-g value shall be kept to a minimum not exceeding 50% of the qualification level.

(8) The sinusoidal and random vibration conditions shall be imposed sequentially.

(9) For all vibration test conditions refer to Paragraph__________, "Vibration", for limitation of amplification factors.

(10) Unless specifically stated no temperature change shall be imposed on the equipment which may produce a thermal shock.

(11) All temperature test shall commence after the equipment has been stabilized at the specified temperature levels.

(12) Equipment which is cooled by the ECS cooling loop shall be supplied with a representative heat sink which shall not exceed the allowable temperature limits.

(13) Maximum allowable temperature shall not be exceeded on any equipment under test at ambient pressure conditions.

RELIABILITY BOUNDARY CONDITIONS TABLE

Mission Plan	Condition	Levels and Exposure	Remarks
Prelaunch Conditions	Acceptance Test		To be conducted in accordance with Table ________, Requirements for Acceptance Test.
	Integration and Checkout Subsequent to Acceptance Test and Prior To Launch	Ambient Conditions - The ____________ ____________ shall be operated for ________ hours/cycles in accordance with Paragraph __________, Operational Test Procedures.	This condition simulates the total operating time accumulated on the ______________ from point of shipment to Grumman through all checkout and acceptance testing prior to launch at AMR.
	Humidity-Temperature	In accordance with MIL-STD-810 (USAF) 14 June 1963, Method 507, Procedure 1. Modify high temperature to +110°F, low temperature to +68°F. Reduce number of continuous cycles to two (2) for a total test time of not less than 48 hours.	
	Temperature	- 20°F for 12 hours and +110°F for 12 hours During each test expose specimen to 360 BTU/ft^2/hr.solar radiation for 6hrs	Equipment non operating during test.
	Salt Spray Sand and Dust Rain Fungus	In general, these environments shall not be imposed.	

RELIABILITY BOUNDARY CONDITIONS TABLE

Mission Plan	Condition	Levels and Exposure	Remarks
Prelaunch Conditions	Shock	In accordance with MIL-STD-810 Method 516 Procedure 1. Modify shock pulse to saw tooth, 15g peak 11 ± 1 ms rise, 0-2 ms decay. Three (3) pulse per direction for total of 18 pulse.	
	Vibration	Sinusoidal Sweep Rise & Fall $\frac{1}{2}$ Octave/min. 5-7.2, 0.5 inch DA 7.2-26 cps ± 1.3g 26-52 cps, 0.036 " DA 52-500 cps, ± 5.0g One (1) sweep per each of the three mutually perpendicular axes.	Resonant frequencies shall be detected and recorded. Equipment over 100 lbs. shall be vibrated to the maximum frequency specified in Figure 514-8 Method 514, MIL-STD-810 (USAF)
Launch/Boost and Space Flight (Translunar)	Vibration & Temperature	Launch & Boost Input To Equipment Supports From Exterior Primary Structure Sinusoidal: 5-18.5 cps 0.177" DA Sweep Rise & Fall 3.4 Octave/min.: 18.5-100 cps 3.1g Random: 10-23 cps 12 db/oct.rise to 17 min/axis: 23-80 cps 0.0196 g^2/cps 51 min/total: 80-110 cps 12 db/oct. rise to 110-950 cps .0587 g^2/cps 950-1200 cps 12 db/oct. rolloff to 1200-2000 cps .0196 g^2/cps	See Remarks on following page.

RELIABILITY BOUNDARY CONDITIONS TABLE

Mission Plan	Condition	Levels and Exposure	Remarks
Launch/Boost and Space Flight (Translunar)	Vibration & Temperature (continued)	Launch & Boost Input To Equipment Supports From Interior Primary Structure Sinusoidal — 5-16 cps 0.177 " DA Sweep Rise & Fall — 16-100 cps 2.21g 3/4 Octave/min Random — 20-2000 cps .047g^2/cps 17 min/axis 51 min/total Space Flight (Translunar) Input To Equipment Supports From Primary Structures Sinusoidal — 5-16 cps 0.177 " DA Sweep Rise & Fall — 16-100 cps 2.21g $2\frac{1}{4}$ Octave/min. Random — 50-100 cps 12 db/oct. rise to 6 min/axis — 100-1000 0.0313g^2/cps 18 min/total — 1000-2000 12 db/oct. rolloff Temperature — Equip. Bay:0°F to + 160°F Cabin Equip:0°F to + 160°F Prop.Comp: + 40°F to + 100°F Launch & Boost-LEM External -65°F to +160°F Space Flight-LEM External: -300°F to 250°F	Each orthogonal direction shall include the appropriate exposure time of Launch and Boost and Space Flight Vibration. Equipment on standby operation during Launch and Boost or Translunar phase of mission shall be operated continuously throughout this vibration condition under exposure to the maximum temperature applicable for its location in the LEM. Equipment not operating during Launch and Boost and Space Flight (Translunar) phase of LEM mission shall be vibrated under exposure to the minimum temperature applicable for its location in the LEM.

RELIABILITY BOUNDARY CONDITIONS TABLE

Mission Plan	Condition	Levels and Exposure	Remarks
Launch/Boost and Space Flight (Translunar)	Acceleration	Launch/Boost: + 6.50g x-axis (eyeballs downward) Three Minutes Space Flight: - 1.60g x-axis (eyeballs upward) Three Minutes	Equipment non operational
Space Flight (Translunar)	Thermal-Vacuum	Pressure: Less than 1 x 10^{-5} mm Hg Temperature: Location / Heat Sink Temp. / Surroundings Temp. / Exposure (days) Equip.Bay / + 35°F / 0°F / 4 Equip.Bay / +130°F / +160°F / 4 Cabin / + 35°F / 0°F / 1 Cabin / +130°F / +160°F / 1 Prop.Comp. / - / + 40°F / 4 Prop.Comp. / - / +100°F / 4 Ext. Surface / - / - / 4 Ext. Surface / - / - / 4	Equipment shall be operated in accordance with its Mission Operating Profile of Table ____
	Oxygen Atmosphere	Cabin Equipment Only Exposure Time (4) Days Control cabin pressure to 5.8 ± 0.3psia, 100% Oxygen, Temperature cycle, 50°F dwell for (4)hrs. increase to 90°F in 2±.5 hrs. Dwell (4)hrs. at 90°F. Decrease to 50°F in 2 ±.5 hrs.	Equipment shall be operated in accordance with the Mission Operation Profile of Table ____

RELIABILITY BOUNDARY CONDITIONS TABLE

Mission Plan	Condition	Levels and Exposure	Remarks
Lunar Excursion (Ascent & Descent)	Vibration & Temperature	Input To Equipment Supports From Primary Structure Sinusoidal 5-16 cps 0.177" DA Sweep Rise & Fall 16-100 cps 2.21g ½ Octave/min. One cycle for Descent Stage Equipment, two cycles for Ascent Stage Equipment. Random* 20-85 cps .0407 g^2/cps 85-100 cps 12 db/oct. rise to 100-1000 cps .0783 g^2/cps 1000-1200 cps 12 db/oct. rolloff to 1200-2000 cps .0407 g^2/cps *Twenty (20) minutes per axis for a total of 60 min. for Ascent Stage Equip. 11.5 min. per axis for a total of 34.5 min. for Descent Stage Equipment. Temperature Equip.Bay + 160°F Cabin Equip + 160°F Prop.Comp. + 100°F LEM External - 300°F to +250°F	Equipment shall operate continuously throughout temperature vibration exposure. LEM external equipment shall be vibrated under temperature extreme most deleterious to its performance.
	Ultra High Vacuum	Less than 1 x 10-9 mm Hg Eight (8) days for external cabin (including equipment bay, prop.comp. and external LEM)	This condition shall be imposed on equipment susceptible to ultra high vacuum degradation. The appropriate equipment shall be operated in accordance with Mission Operat.Profile Table

RELIABILITY BOUNDARY CONDITIONS TABLE

Mission Plan	Condition	Levels and Exposure	Remarks
Lunar Excursion Ascent/ Descent	Lunar Landing Shock	One (1) Downward Shock (x-axis) Trapezoidal Wave Shape 10-20 ms duration at 9.2g level.	General Note (5) applies

EXPOSURE TIME AT QUALIFICATION STRESSES

DURING RELIABILITY ASSURANCE TESTS

Peak Condition	Exposure Time (or Cycles)
Vibration	3 minutes per each of the three axes, x, y and z.
Random	One Sweep, 5-2000-5 cps for each of the three axes x, y and z.
Sine	Sweep rate at 2 octave/minute
Acceleration	One minute - 3 planes simultaneously
Shock	One shock per plan for each of 6 planes

APPENDIX B

CRITICALITY LISTING

HARDWARE UTILIZATION: RELIABILITY ASSURANCE TESTS

	Subsystem Equipment	Criticality (See Note 1) I	II	III	Quantity For Test
	PROPULSION (See Note 2)				
Gases	Helium Tank	X			4
	Helium Tank Fill Pressurization Sensor	X			
	Squibb Valve	X			
	Filter	X			
	Regulator	X			
	Quad Check Valve	X			
	Solenoids	X			
	Burst Dise	X			
	Relief Valve Vent	X			
Liquids	Propellant Tank	X			
	Propellant Tank Fill Pressurization Sensor	X			
	Burst Disc	X			
	Filter	X			
	Solenoids	X			
	Throttle	X			
	Manifolds and Injectors	X			
	Ground Test Connections	X			
	Combustion Chamber and Nozzle	X			
	Gimbling Control	X			
	Throttle System	X			
	Reaction Control Feed	X			
	Squibb	X			
	Quad Check Valve	X			
	Orificies	X			4
	STABILITY AND CONTROL				
	Rate Gyro Assembly	X			4
	Descent Engine Control Assembly	X			
	Attitude Thrust Control Assembly	X			
	Guidance Coupler Assembly	X			
	Pilot Attitude Controller Assembly	X			
	Pilot Thrust Controller Assembly	X			
	Back-up Guidance Computer	X			
	Back-up Attitude Reference Assembly	X			4

APPENDIX B

(continued)

HARDWARE UTILIZATION: RELIABILITY ASSURANCE TESTS				
Subsystem Equipment	Criticality (See Note 1) I	II	III	Quantity For Test
COMMUNICATION SUBSYSTEM				
S-Band Steerable Antenna			X	2
S-Band Lunar Surface Erectable Antenna			X	
S-Band Omni Antenna			X	
S-Band Coaxial Switch (R-F)			X	
S-Band Diplexer			X	
S-Band Transceiver			X	2
S-Band Power Amplifier			X	3 (Note 3)
S-Band Cables and Connectors			X	2
VHF Lunar Surface Antenna		X		3
VHF Omni Antenna		X		
VHF Coaxial Switch		X		
VHF Diplexer		X		
VHF Transceiver		X		
VHF Cables and Connectors		X		3
Audio Center			X	2
*Premodulation Processor (PMP)			X	2
DISPLAYS AND CONTROLS				
Navigation and Guidance Display	X			3
Operation Status Display	X			
Descent Engine Control Assembly	X			
Radar Analog and OMU Displays	X			
Indicators	X			
Lamps	X			3
ELECTRICAL POWER				
Supercritical Oxygen Tank	X			4
Gaseous Oxygen Tank	X			
Supercritical Hydrogen Tank	X			
Check Valves	X			
Interstage Disconnect	X			
Fill Valve and Cap	X			
Vent Valve and Cap	X			
Pressure Relief Valve	X			
Solenoid Shut-off Valve	X			
Heat Exchanger	X			4

APPENDIX B

(continued)

HARDWARE UTILIZATION: RELIABILITY ASSURANCE TESTS

Subsystem Equipment	Criticality (See Note 1) I	II	III	Quantity For Test
ELECTRICAL POWER (continued)				
Tank Pressure Sensor		X		3
Tank Quantity Sensor		X		
Tank Temperature Sensor		X		
Tank Heater Switch		X		3
Subsystem Plumbing		X		4
Fuel Cell Assembly		X		4 (Note 3)
*Batteries (Back-up FCA)	X			4
NAVIGATION AND GUIDANCE				
Rendezvous Radar/Transponder	X			4
Landing Radar		X		3
ENVIRONMENTAL CONTROL				
Atmosphere Revitalization Section	X			4
Oxygen Supply and Cabin Control System	X			
Heat Transport Section	X			
Water Management Section	X			
Cryogenac Oxygen Storage Section	X			
Cold Plate Section				4
INSTRUMENTATION				
Recorder			X	2
Data Storage Equipment			X	2
Pulse Code Modulation "PCM"			X	2
In-flight Test System		X		3
Sensors		X		
Signal Conditioner		X		
Displays		X		3
CREW PROVISIONS*				
Crew Support and Restraint System	X			4
Restraint Components		X		3
Crew Ascent/Descent Provisions			X	2
Display and Control Panel and Assembly and Installation		X		3
Lighting System	X			4
Individual Lighting Components		X		3
Waste Management		X		3
Water Dispensing Provisions		X		3
Other Crew Provisioning Devices			X	2

APPENDIX B
(continued)

Subsystem Equipment	Criticality (See Note 1)			Quantity For Test
	I	II	III	
REACTION CONTROL				
Helium Pressurization System	X			4
Helium Tank	X			
Helium Fill and Vent Disconnect	X			
Explosive Squibb Valve	X			
Quad Check Valve	X			
Burst Disc	X			
Propellant Fill and Vent (Drain) Coupling	X			
Fuel Tank	X			
Oxidizer Tank	X			4
STRUCTURE				
Landing Gear System	X			4
Docking Mechanism	X			4
Antenna Erection			X	2
Tank Supports	X			4
Engine Supports		X		3
Separation System (Ascent/Descent)	X			4
Landing Gear Skirt	X			
Latching Gear	X			
Booster/Adapter Separation	X			4

NOTE 1: Redundant components receive the same rating as the subsystem.

NOTE 2: Ascent and Descent Propulsion will be placed in criticality Class I category.

NOTE 3: Given State of Art considerations.

NOTE 4: Criticality of items marked with asterisk (*) are those which have been revised since 18 November 1963.

APPENDIX C

TEST DOCUMENTATION REVIEW

List of Abreviations

Document Designation	
LAV	LEM AVO
LMO	LEM Memorandum
LTP	LEM Test Plan
LPL	LEM Plan
LTP	LEM Test Report
LSP	LEM Specifications
SEM	Servo Engineering Memorandum
SER	Servo Engineering Report
PWA	Pratt & Whitney Aircraft Document
SV HSER	Hamilton Standard Engineering Report
R	Rocketdyne
MTP	Marquardt Test Plan

APPENDIX C

TEST DOCUMENTATION

Document Number	Subject
LAV-470-2	LEM Vibrational Environments for Design and Procurement of Equipment Revision of
LMO-611-19	Detailed Test Plan for LEM 1
LMO-615-1	Preliminary Flight Test Plan for Manned Earth Orbital Flights of LEM 5, 6, 7 (System Test Vehicle)
LMO-613-5	Test Plan Development Schedule for LEM 3
LMO-280-27	Rivet Sealing Test
LMO-390-106	LEM Wiring Insulation Materials and Test Programs
LMO-390-95	Test Program LEM Wiring (Ser #7)
LMO-390-000	EPS Test Support Requirements at WSMR
LPL-610-2	LEM Checkout at AMR
LSP-390-4	Qualification Table for Battery Charger
LSP-380-1	Communications Subsystem Design Control Specification
LSP-350-306	Indicator, Thrust-To-Weight Ratio Design Specification
LTC-914-13002	Resistance of Prestretched Plex 55 & Plex II UVA to Freon TF Solvent

TEST DOCUMENTATION (continued)

Document Number	Subject
LTP-390-1	Preliminary Test Plan for the Development and Qualification of the Power Generator System
LTP-900-1000	Plan for Issuance of LEM Hardware QSL
LTP-904-1001	Plan for Landing Gear Component Development Tests
LTP-905-11001	Plan for Vibration Tests of Structural Elements
LTP-908-11001	Plan for Vibration Tests of Display Components
LTP-908-13001	Plan for Development Test of Electrical Switches
LTP-912-13001	Plan for Environmental Test of LEM Wire Assembly
LTP-914-13001	Plan for Screening Tests of LEM Window Materials
LTP-915-12001	Plan for Thermal Vacuum Test of Skin Panels
LTP-932-17001	Test Plan for LTA-2 Landing Stability Demonstrator
LTP-933-24001	Preliminary Plan for Pressure Tests of LTA-3 Cabin Structure
LTP-937-23001	Test Plan LTA-7 Manned LEM
LTR-905-14002	Results of Propulsion Test Unit Propellant Tank Tests

APPENDIX C
TEST DOCUMENTATION (continued)

Document Number	Subject
LTR-960-1200	Equipment Heat Transfer to Cold Plates at High Vacuum
SEM-63-89	LEM Wiring Insulation
L-1006	Marquardt Program Plan
MTP-0014	Marquardt Duster Development Plan
R-5205-6	Rocketdyne LEM Monthly Progress Report
R-5205-5	Rocketdyne LEM Monthly Progress Report
R-5205-4	Rocketdyne LEM Monthly Progress Report
No.8438-6024-SC000	Space Technology Labs Progress & Status Report
No.8438-6033-SC000	Space Technology Labs Progress & Status Report
No.8438-6041-SC000	Space Technology Labs Progress & Status Report
No. 4	Bell Monthly Progress Report
PWA 2402	Test Plan for LEM Fuel Cell Assembly
PWA 2406	Reliability Plan for LEM Fuel Cell Assembly
PWA 2408	LEM Monthly Progress Report

APPENDIX C

TEST DOCUMENTATION (continued)

Document Number	Subject
PWA 2409	LEM Fuel Cell Assembly Experimental Model End Item Acceptance Test Plan
PWA 2410	Design Data Report for PC 6A-1 LEM Fuel Cell Assembly
PWA 2411	Preliminary Reliability Report for the PC 6A-1 LEM Fuel Cell Assembly
PWA 2412	LEM Fuel Cell Assembly Monthly Progress Report
PWA 2414	LEM Fuel Cell Assembly Monthly Progress Report
SV HSER 2790-2	LEM Environmental Control and Life Support Subsystem Progress Report
SV HSER 2790-3	LEM Environmental Control and Life Support Subsystem Progress Report
SV HSER 2790-4	LEM Environmental Control and Life Support Subsystem Progress Report
SV HSER 2807	LEM Environmental Control Subsystem Quarterly Design Report

6.0 MAINTAINABILITY

6.1 Propulsion Subsystem

6.1.1 Pre-launch Accessibility

Access to the Propulsion Subsystem is required for installation, test, checkout, repair, and service.

The Ascent Engine may be reached from inside the Ascent Stage by removing the ascent engine recess in the equipment tunnel.

Access to the Descent Engine may be gained from the top of the descent stage if the ascent stage is not installed. However, at present the design configuration of the descent stage permits no accessibility to the descent engine when the ascent and descent stages are mated.

Present pre-launch checkout plans (Reference LPL-610-2) call for the final mating of the ascent and descent stages at approximately T minus 60 days. Consequently, any maintenance action will require demating the LEM and possibly an extensive delay in launch.

An informal demonstration held in the Plant 5 LEM Mock-Up Area (Reference LMO-550-174) indicated the practicability of access to the descent engine through the bottom of the descent stage.

There are certain parts (Thrust Chambers, Injectors, Nozzle Skirt, etc.) that may not be replaced without a hot-fire re-calibration. Failure of these parts will, under any accessibility conditions, require a demating of the LEM with subsequent launch setback.

There are other parts (Transducers, Harnesses, Lines, Solenoids, etc.) that may be replaced without a hot-fire re-calibration. Accessibility to the descent engine should be provided so that a failure of this class of parts does not cause an extensive launch delay.

As a result of the demonstration, the following recommendations were made (Reference LMO-550-174):

a. Heat shield for descent engine should consist of removable panels or segments to permit access into the engine compartments.

b. The gimbal actuators should have an external source of power for rotating the engine to one side to improve accessibility.

6.1.1 (continued)

c. Work stands should be designed to permit access into the engine compartment without damage to the engine.

d. Parts (Transducers, Solenoids, etc.) that can be replaced without requiring hot-fire re-calibration should be designed so that they can be replaced and checked out on the engine.

6.1.2 Manual Operations (In-Flight/Lunar)

An analysis was performed to determine the practicability of "plugging the astronaut into the loop" to improve inherent reliability of the Propulsion Subsystem by providing redundant manually-controlled valves in the helium pressurization or propellant supply systems.

The 1 November 1963 Quarterly Reliability Status Report (LPR-500-3) indicated that the Helium Regulation Subassembly was the greatest contributor to Mission Success Unreliability of the Propulsion Subsystem. The maintainability analysis indicated that a manually operated valve could be installed parallel to the helium regulator valve and substantially increase the reliability of the subassembly. However, a change in interpretation of the ground rules for calculating reliability could provide a similar substantial increase in predicted reliability. The reliability for the Propulsion Subsystem was calculated considering all parallel items "in series" for mission success. This accounted for the relatively low "mission success" reliability of the Propulsion Subsystem.

A revised interpretation of the ground rules permits calculating the helium regulator valves as parallel units. The reliability "gain" due to the new interpretation was approximately as large as the gain with the redundant manual valve.

It is therefore recommended that the installation of a manually operated valve not be considered.

6.1.2 (continued)

Table 6.1 shows the comparison of the reliabilities of the Helium Regulation Subassembly discussed above.

TABLE 6.1

HELIUM REGULATION SUBASSEMBLY - DESCENT ENGINE HELIUM PRESSURIZATION ASSEMBLY

	Mission Success Reliability
Original Interpretation Of Rules	.986417
Installation Of Redundant Valve	.999136
New Interpretation Of Rules	.999074

6.2 Navigation and Guidance Subsystem

An investigation of the Reliability gains attainable through design of subassemblies which would be interchangeable between the Rendezvous Radar (RR), Landing Radar (LR), and Transponder (XPDR) was documented in LED-550-15.

The concept of obtaining spares without substantial weight penalty by cannibalizing the LR on the lunar surface prompted this study. The study was based on assumptions deduced from preliminary data obtained from RCA. The advantages and disadvantages of interchangeable subassemblies were aired and the following reliability gains were predicted:

Equipment	(R) Reliability Predicted	ΔR With LR Spares	R + ΔR
RR	.99903	.00015	.99918
XPDR	.99977	.00007	.99984
RR + XPDR	.99879	.00022	.99901

6.2 (continued)

The general conclusion of this investigation was that some small reliability gains could be obtained through interchangeability and further effort should be extended in this direction.

6.3 Ground Support Equipment

Preliminary investigation has begun on the determination of pre-launch repair times for all LEM Replaceable Assemblies (LRA) and GSE. Rapid replacement of failed assemblies will be an important factor in enhancing the probability of launching within the launch window. Every effort will be extended toward identifying high failure rate assemblies, and providing the maintenance planning to accomplish rapid replacement. The relationship between failures rates and repair rates of assemblies will be investigated to assist in the identification of the assemblies which could possibly cause undue delay during pre-launch activities. Further investigation and trade-off studies will be made to assure a reasonable balance between Reliability and Maintainability.

7 PARTS CONTROL AND EVALUATION

7.1 Acceptable Parts List

In addition to the listings of the various part types deemed acceptable for use in LEM equipments, the Acceptable Parts List for LEM will include deratings and application notes, specifications denoting significant part characteristics, and approved sources for each part. The first edition of the Acceptable Parts List will include resistors, capacitors, transistors and semiconductor diodes. Other classes of parts will be added in subsequent versions of the document.

Anticipated lunar environments were considered wherever practicable in the generation of the parts listings, although little test data is yet available in several areas such as the effects of proton bombardment or of a hard vacuum even well below our requirements.

Various other problems affecting part selection and applications have been worked on. Among these are lead materials (and soldering versus welding), the development of a system for assigning LEM part identification numbers, and the extent to which controls on parts for ground support equipment are to be implemented.

Discussions on various parts under consideration as candidates for inclusion in the Acceptable Parts List were conducted with the manufacturers concerned, including the Hi Q Division of Aerovox, Allen-Bradley, Amphenol, Bendix, Corning, Electro Motive Manufacturing, Erie, Fairchild Semiconductor, General Electric, IRC, JFD Electronics, Mepco, Texas Instruments, Western Electric, and numerous others.

7.2 Parts Procurement Specifications

Major modifications were made in the drafts of several of the parts procurement specifications. Work is required in this area because, although the military specifications have established qualification tests for many parts under many environmental conditions, they do not adequately cover the environments and stresses that the parts may see during the lunar mission. The parts procurement specifications being generated here are intended to establish some test levels and qualification procedures more nearly representative of anticipated mission environments, supplementing these provisions with particular "culling" requirements

7.2 (continued)

(such as power aging) aimed at eliminating infant mortality and stabilizing part characteristics. Other reliability requirements (such as traceability) are also included when applicable.

LSP numbers for these procurement specifications, as well as LSC numbers for identification of parts, are under consideration for assignment.

7.3 Parts Application

In addition to the transistor and semiconductor diode listings for the Acceptable Parts List, selector charts for these two devices are being generated. These charts group the transistors and diodes by function and by the design characteristics most likely to be significant to the design engineer, to facilitate his use of LEM acceptable types in his circuitry.

Work has continued also on derating factors for listed parts, design tolerances where applicable, and the application notes and cautions pertinent in each case. Thermal properties of various relevant materials (such as encapsulating or lead materials), the lack of convection cooling in vacuum, and welding versus soldering conditions were among the thermal considerations weighed in establishing deratings.

7.4 Anticipated Effort For The Next Quarter

Additional categories of parts, and additional parts within these categories, will be considered for inclusion in revised versions of the LEM Acceptable Parts List.

Deratings and application notes will continue to constitute a major portion of the work, as will the generation of procurement specifications.

The workload in the area of non-standard parts and their applications is expected to increase as the engineering designs progress.

8 DOCUMENTATION RELEASED DURING THE REPORT PERIOD

8.1 Memorandums

Number	Date	Title
LMO-550-161	11-5-63	Descent and Ascent Engine Specification Change
LMO-550-162	11-6-63	Marquardt Program Plan - Report L-1006, dated 22 September 1963
LMO-550-163	11-13-63	Reliability Test Data Analysis
LMO-550-164	11-14-63	Brushless A-C Motors on the LEM Vehicle
LMO-550-165	11-14-64	Report on the Trip to Raytheon Company on 17 and 18 October 1963 to Ascertain Amplitron Status
LMO-550-166	11-18-63	Definitions of Mission Success for Hamilton Standard Reliability Estimates
LMO-550-167	11-19-63	GAEC-NASA/MSC Meeting 29 and 30 October 1963, Office City, Houston
LMO-550-168	11-23-63	GAEC Reliability Evaluation of Subcontractors Landing Radar Proposals
LMO-550-169	11-22-63	Trip Report on Presentation by NASA at AMR on Their Checkout and Maintenance Experiences on the Mercury and Gemini Program
LMO-550-170	11-27-63	Contingency Analysis Objectives and Outlines
LMO-550-171	11-28-63	Review of Autonetics "PCM Telemetry for LEM" EM-0363-170 dated 21 October 1963
LMO-550-172	12-3-63	Evaluation of PWA Preliminary Reliability Report for Fuel Cell Assembly (PWA-2411, Received 11-9-63)
LMO-550-173	12-3-63	Revisions to Specification LSP-390-501, Dated 12 August 1963
LMO-550-174	12-3-63	Descent Engine Acceptability

8.1 (continued)

Number	Date	Title
LMO-550-175	12-4-63	Trip Report to Goddard Space Flight Center, Dated 26 November 1963
LMO-550-176	12-4-63	Evaluation of ReliabilitySection of the Hamilton Standard Program Plan for the LEM Environmental Control and Life Support Subsystem, Dated 22 September 1963
LMO-550-177	12-6-63	Minutes of Reliability Coordination Meeting of Hamilton Standard LEM ECS GAEC on 4 December 1963
LMO-550-178	12-6-63	Reliability Input to Subsystem Requirements Specification
LMO-550-179	12-7-63	LEM Stabilization and Control System Rate Gyro Assembly, Vendor Proposals, Evaluation Of
LMO-550-180	12-9-63	PROPRIETARY
LMO-550-181	12-10-63	PROPRIETARY
LMO-550-182	12-13-63	Reliability Comparative Design Analysis For RCS
LMO-550-183	12-16-63	Ascent and Descent Engine On-Off Control
LMO-550-184	12-18-63	Clean Room Procedure Doctrination
LMO-550-185	1-3-64	LMO-320-86, A Review of Capacitors and Resistors for the LEM Acceptance Report Test
LMO-550-186	1-4-64	PROPRIETARY
LMO-550-187	1-8-64	Feasibility Factors
LMO-550-188	1-8-64	Review of PWA Revised Reliability Plan PWA 2406 Revision A, dated 6 December 1963, Received in LEM Reliability 16 December 1963
LMO-550-189	1-10-64	(cancelled - changed to LED-550-12)
LMO-550-190	1-9-64	Rocketdyne LEM Monthly Progress Report No. R-5205-6, Received 5 December 1963

8.1 (continued)

Number	Date	Title
LMO-550-191	1-9-64	STL Reliability Report No. 8438-6038, Received 6 December 1963
LMO-550-192	1-9-64	Bell Aerospace Systems Maintainability Analysis Reports
LMO-550-193	1-9-64	DECA and GDA Reliability (Single Motor vs Two Motor Actuator Configuration)
LMO-550-194	1-16-64	PROPRIETARY
LMO-550-195	1-27-64	Rocketdyne Reliability Report R-5226-2
LMO-550-196	1-29-64	Proposed Reliability Test Plan, Brushless D-C Motors
LMO-550-197	1-30-64	Review of Bell Aerosystems Ascent Engine, Reliability Report No. 8258-932003
LMO-550-198	1-31-64	Comments of STL Descent Engine Support Plan

8.2 LED's (Engineering Data)

Number	Date	Title
LED-550-13	11-5-63	Pryotechnic Circuit Configuration Study
LED-550-14	11-8-63	RCS Failure Mode and Effects Analysis
LED-550-15	12-12-63	Improved Reliability with Lunar Repair of the Rendezvous Radar and Transponder
LED-550-16	12-15-63	Reliability Analysis of Instrumentation Subsystem
LED-550-17	1-15-64	A Proposed Method for Utilizing Statistical Test Designs and Propulsion Rig Test Programs
LED-550-18	11-20-63	Ascent Propellant Tankage Configurations Study
LED-550-19	12-4-63	Weight Reliability Configuration Study of the RCS
LED-550-20	12-12-63	Weight-Reliability Configuration Study of the ECS